Society for Industrial and Applied Mathematics

2nd Annual Meeting of SIAM Central States Section

UNIVERSITY OF ARKANSAS AT LITTLE ROCK

September 30, 2016 - October 2, 2016

Society for Industrial and Applied Mathematics

Organizing Committee

Committee Chair and Section President
Xiaoming He
Missouri University of Science and Technology (S&T)

Section Vice President
Erik Van Vleck
University of Kansas

Section Secretary
Xiu Ye
University of Arkansas at Little Rock

Section Treasurer
Stephen Pankavich
Colorado School of Mines

Committee Member
Eric Kaufmann
University of Arkansas at Little Rock

Committee Member
Zhu Wang
University of South Carolina

Conference Coordinator
Michelle Wiginton (S&T)

Conference Secretary
Tammy Mace (S&T)

Welcome to SIAM Central States Section Second Annual Meeting

Welcome to University of Arkansas at Little Rock and the second annual meeting of the SIAM Central States Section.

The second meeting promises to be an excellent event for the growing SIAM section. The conference features presentations by four plenary speakers, over 200 invited and contributed presentations split between 47 parallel sessions. We are honored to have Irene Gamba, Weizhang Huang, Paul Martin, and Bob Pego as plenary speakers.

One of the primary goals of the new SIAM Central States Section is to promote communication and collaboration among SIAM members in the central region, consisting of Arkansas, Colorado, Iowa, Kansas, Mississippi, Missouri, Nebraska, and Oklahoma. We hope that you take advantage of the many opportunities to network with colleagues from the central region and many other locations.

We are very grateful to SIAM for the support in starting the SIAM Central States Section. We also thank all of the individuals who contributed to the organization of the conference, University of Arkansas at Little Rock, Missouri S&T and SIAM for their support.

We hope everyone enjoys the conference and finds it valuable. Thanks to everyone for attending and participating, and for supporting our new SIAM Central States Section.

About SIAM Central States Section – siamcentral2016.mst.edu/

The SIAM Central States Section was formed in 2014 to serve SIAM members in Arkansas, Colorado, Iowa, Kansas, Mississippi, Missouri, Nebraska, and Oklahoma. The purpose of this section is to enhance the communication among the section members, promote the collaboration for both basic research and applications of mathematics to industry and science, represent applied and computational mathematics, and support the SIAM mission in the central region of the USA.

The proposed activities for the SIAM Central Section include annual section meetings, seminars and workshops for advanced topics of common interests of the section members, encouraging new SIAM student chapters and facilitating the SIAM student chapters in the central region to connect together, promoting collaboration in applied mathematics and its applications to industry and science, and expanding the influence of SIAM in the central states.

Participation in SIAM Central States Section activities will be open to all institutions and industries in the region with an interest in applied and computational mathematics.

SIAM Central States Section Officers:

President
Xiaoming He
Missouri University of Science and Technology

Vice President
Erik S. Van Vleck
University of Kansas

Treasurer
Stephen D. Pankavich
Colorado School of Mines

Secretary
Xiu Ye
University of Arkansas at Little Rock

Schedule at a Glance

Friday, September 30, 2016

MORNING SCHEDULE
Stella Boyle Concert Hall-Fine Arts Building
Chair: Dr. Minh Nguyen

8:00 a.m. – 3:30 p.m.
Registration Desk Open

9:00 a.m. - 9:20 a.m.
Welcome Remarks

9:20 a.m. - 10:10 a.m.
Plenary Speaker
Irene Gamba

10:10 a.m. - 10:40 a.m.
Refreshment Break

10:40 a.m. - 11:30 a.m.
Plenary Speaker
Weizhang Huang

11:30 a.m. - 1:20 p.m.
Lunch on your own

AFTERNOON SCHEDULE
*EIT and ETAS Buildings**

1:30 p.m. - 3:10 p.m.
Parallel Sessions
*EIT and ETAS Buildings**
See schedule on pages 4-5 for details.

3:40 p.m. - 4:20 p.m.
Transportation to Clinton Library
If you do not have a car or cannot find a ride from other conference participants, please let the registration desk know and wait at the registration desk for the shuttle at 3:40 p.m.

5:00 p.m. - 7:00 p.m.
Social Mixer
(refreshments, but not a meal)
Room 42, Clinton Library

Saturday, October 1, 2016

MORNING SCHEDULE
Stella Boyle Concert Hall-Fine Arts Building
Chair: Dr. Eric Kaufmann

8:00 a.m. – 5:00 p.m.
Registration Desk Open

9:00 a.m. - 9:20 a.m.
Discussion with Potential Section Officer

9:20 a.m. - 10:10 a.m.
Plenary Speaker
Paul Martin

10:10 a.m. - 10:40 a.m.
Group Photo & Refreshment Break

10:40 a.m. - 11:30 a.m.
Plenary Speaker
Bob Pego

11:30 a.m. - 1:20 p.m.
Lunch on your own

AFTERNOON SCHEDULE
*EIT and ETAS Buildings**

1:30 p.m. - 3:10 p.m.
Parallel Sessions
*EIT and ETAS Buildings**
See schedule on pages 6-7 for details

3:10 p.m. - 3:50 p.m.
Refreshment Break

3:50 p.m. - 5:30 p.m.
Parallel Sessions
*EIT and ETAS Buildings**
See schedule on pages 8-9 for details.

6:30 p.m. - 8:00 p.m.
Banquet
Donaghey Student Center

Sunday, October 2, 2016

MORNING SCHEDULE
*EIT and ETAS Buildings**

8:00 a.m. – Noon
Registration Desk Open

8:30 a.m. - 10:10 a.m.
Parallel Sessions
*EIT and ETAS Buildings**
See schedule on pages 10-11 for details.

10:10 a.m. - 10:40 a.m.
Refreshment Break

10:40 a.m. - 12:20 p.m.
Parallel Sessions
EIT and ETAS Buildings
See schedule on page 12 for details.

12:20 p.m.
Meeting Adjourns

**PLEASE NOTE*
Engineering and Information Technology Building (EIT) and the Engineering Technology and Science Building (ETAS) are connected.

Conference Schedule
Friday, September 30, 2016

MORNING SCHEDULE
Stella Boyle Concert Hall –
Fine Arts Building

8:00 a.m. – 3:00 p.m.
Registration Desk Open

9:00 a.m. - 9:20 a.m.
Welcome Remarks

9:20 a.m. - 10:10 a.m.
Plenary Speaker

Irene Gamba
Conservative Solvers for Collisional Kinetic Boltzmann and Landau-Poisson Systems

10:10 a.m. - 10:40 a.m.
Refreshment Break

10:40 a.m. - 11:30 a.m.
Plenary Speaker

Weizhang Huang
A New Implementation of the MMPDE Moving Mesh Method and Applications

11:30 a.m. - 1:20 p.m.
Lunch on your own

AFTERNOON SCHEDULE

1:30 p.m. - 3:10 p.m.
Parallel Sessions
See schedule on right.

3:20 p.m. - 4:20 p.m.
Transportation to Clinton Library

5:00 p.m. - 7:00 p.m.
Social Mixer
(refreshments, but not a meal)
Room 42, Clinton Library

Parallel Sessions | 1:30 p.m. - 3:10 p.m. - *EIT and ETAS Buildings*

EIT 219: Recent Advances on Numerical Methods for Interface Problems

Organizer: Xu Zhang, James B. Collins
Speakers: Long Chen, Jeb Collins, Tao Lin, Cuiyu He, Songming Hou

1001 - An Interface-Fitted Mesh Generator And Virtual Element Methods For Elliptic Interface Problems
1002 - A Posteriori Error Estimation For A Cut Cell Method With Uncertain Interface Location
1003 - Applications of Immersed Finite Element Methods
1004 - A Posteriori error estimation for nonconforming finite element methods
1005 - Numerical Methods For Solving Linear And Nonlinear Interface Problems

EIT 224: Partial Differential Equations: Analysis, Computation, Modeling, and Applications

Organizer: John Singler, Weiwei Hu
Speakers: Tong Li, Mathew Johnson, Samuel Walsh, Aslihan Demirkaya, Majid Bani-Yaghoub

1006 - Global Wellposedness And Traveling Waves To The PDE Models Of Chemotaxis.
1007 - Dynamics and Stability of Viscous Roll Waves
1008 - Existence And Qualitative Theory Of Stratified Solitary Water Waves
1009 - Numerical Results On Existence And Stability Of Standing And Traveling Waves For The Fourth Order Beam Equation
1010 - Stability Of Travelling And Stationary Waves Arising From A Delayed Hyperbolic–Parabolic Population Model

EIT 318: Highly Accurate and Effective Numerical Methods for Partial Differential Equations

Organizers: Qin Sheng, Abdul Q.M. Khaliq, JaEun Ku
Speakers: Aaron Benham, Matthew Beauregard, Nick Kosmatov, Josh Padgett

1011 - Multiple Positive Solutions Of A Semipositone Fourth-Order Boundary Value Problem
1012 - A Nonlinear Splitting Algorithm for Systems of Partial Differential Equations with self-Diffusion
1013 - The Sturm-Liouville Boundary Value Problem With Impulsive Effects On The Half-Line
1014 - Solving The Degenerate Stochastic Kawarada Equation Via An Adaptive Crank-Nicolson Method

EIT 319: No Talks Scheduled

EIT 321: No Talks Scheduled

EIT 323: Applied and Computational Topology

Organizers: Henry Adams, Patrick Shipman
Speakers: Eric Hanson, Jose Perea, Douglas Heisterkamp, Sara Kalisnik

1015 - Persistence Images: Representing Persistent Homology for Machine Learning
1016 - Directional Features, Projective Coordinates and Classification
1017 - Thin Position Inspired Algorithms For Machine Learning And Data Analysis
1018 - Tropical Coordinates on the Space of Persistence Barcodes

Conference Schedule

Friday September 30, 2016

(Location: EIT and ETAS Buildings for Parallel Sessions)

Parallel Sessions | 1:30 p.m. - 3:10 p.m.

Session Abstracts on pages 15-20

EIT 325: New Numerical Advances on Wave Propagation Problems

Organizer: Yassine Boubendir
Speakers: Yassine Boubendir, Lise-Marie Imbert-Gerard, Wangtao Lu

1019 - Asymptotic Expansions of the Helmholtz Equation Solutions in the Case of Convex Obstacles
1020 - Volume Integral Methods For Wave Propagation In Inhomogeneous Media
1021 - Babich-Like Ansatz For Three-Dimensional Point-Source Maxwell's Equations In An Inhomogeneous Medium At High Frequencies

ETAS 229: Recent Advances in Fractional PDEs

Organizer: Yanzhi Zhang
Speakers: Hong Wang, Mohsen Zayernouri, Xiaofan Li, Joseph E. Pasciak, Siwei Duo

1022 - A Fast Numerical Method for a Bond-Based Linear Peridynamic Model
1023 - Unified Petrov-Galerkin Spectral Methods for High-Dimensional FPDEs
1024 - Numerical Schemes For Integro-Differential Equations Related To Alpha-Stable Processes
1025 - Numerical Approximation of a Variational Problem on a Bounded Domain involving the Fractional Laplacian
1026 - A Fast Algorithm For Solving The Space-Time Fractional Diffusion Equation

ETAS 230: Numerical Approximation And Analysis For Time Dependent PDEs

Organizers: Cheng Wang, Steve Wise
Speaker order: Cheng Wang, Wen-Qiang Feng, Zhen Guan, Lili Ju

1027 - Energy-Stable Pseudo-Spectral Numerical Scheme For The Cahn-Hilliard Equation And The Homogeneous Linear Iteration Algorithm
1028 - Efficient Finite-Difference Geometric Multigrid Solvers for the Cahn-Hilliard Equation
1029 - Unconditional Stable Method for the Amplitude Description of the Phase-Field Crystal model
1030 - Energy Stability and Error Estimates of Exponential Time Differencing Schemes for the Epitaxial Growth Model without Slope Selection

ETAS 480: Some Novel Computational Methods For PDEs

Organizer: Huiqing Zhu
Speakers: Jiangguo Liu, Zhimin Zhang, Zhiyun Yu, Xinxiang Li, Huiqing Zhu

1031 - THex Algorithm and Its Applications in Finite Element Methods
1032 - Polynomial Preserving Recovery for Gradient and Hessian
1033 - Nonconforming Mixed Finite Elements Method For The Three-Dimensional Incompressible Magnetohydrodynamics Equation
1034 - Superconvergence and Extrapolation of Quasi-Wilson Element for Nonsymmetric and Indefinite Problem
1035 - Method Of Fundamental Solutions Using Transformed Angular Basis Functions

ETAS 483: Contributed presentations

Speakers: Necmettin Aggez, Kyle Claassen, Tania Hazra, Michelle Maiden, Zhihan Wei

1036 - A Note on Finite Difference Method for NBVP of the Hyperbolic Type
1037 - Antiperiodic Ground State Theory for Fractional Schr\
1038 - Stable Operator Splitting Method For Free Energy Calculations Of One Atom Model
1039 - Soliton Envelopes in Viscous Conduits
1040 - Three-Dimensional Matched Alternating Direction Implicit (ADI) Schemes for Solving the Heat Equation with Complex Interface

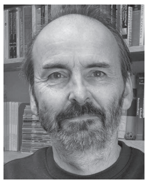
Conference Schedule
Saturday, October 1, 2016

MORNING SCHEDULE
Stella Boyle Concert Hall –
Fine Arts Building

8:00 a.m. – 3:00 p.m.
Registration Desk Open

9:00 a.m. - 9:20 a.m.
Discussion with Potential Section Officer

9:20 a.m. - 10:10 a.m.
Plenary Speaker



Paul Martin
Solving the Wave Equation: Acoustic Scattering in the Time Domain

10:10 a.m. - 10:40 a.m.
Group Photo & Refreshment Break

10:40 a.m. - 11:30 a.m.
Plenary Speaker

Bob Pego
Euler Sprays and Optimal Transportation

11:30 a.m. - 1:20 p.m.
Lunch on your own

AFTERNOON SCHEDULE

1:30 p.m. - 3:10 p.m.
Parallel Sessions
EIT and ETAS Buildings
See full schedule on right.

3:10 p.m. - 3:50 p.m.
Refreshment Break

Parallel Sessions | 1:30 p.m. - 3:10 p.m.

EIT 219: Recent Advances on Numerical Methods for Interface Problems

Organizers: Xu Zhang, James B. Collins
Speakers: Xu Zhang, Marcus Sarkis, Xiaoming He, Ruchi Guo, Nishant Panda

1041 - Superconvergence of Immersed Finite Element Methods.
1042 - Multiscale Variational FETI-DP Discretization For High-Contrast Problems
1043 - Multi-Physics Domain Decomposition Method For Coupled Porous Media Flow And Free Flow
1044 - A Class of Immersed Finite Element Spaces Defined by the Actual Interface
1045 - Stochastic Inverse Problem For Internal Boundaries: A Measure Theoretic Solution

EIT 224: Partial Differential Equations: Analysis, Computation, Modeling, and Applications

Organizers: John Singler, Weiwei Hu
Speakers: John Singler, Weiwei Hu, Taige Wang, Ning Ju

1046 - Model Reduction of a Nonlinear Cable-Mass PDE System with Dynamic Boundary Input
1047 - Boundary Control for Optimal Mixing by Stokes Flows
1048 - A Thixotropic Flow Dynamics Under Large Amplitude Oscillatory Shearing
1049 - Global Regularity And Long-Time Behavior For The Solutions To 2D Boussinesq

EIT 318: Highly Accurate and Effective Numerical Methods for Partial Differential Equations

Organizers: Qin Sheng, Abdul Q.M. Khaliq, JaEun Ku
Speakers: Weizhang Huang, Tiffany Jones, Haiyan Tian, Ruihua Liu

1050 - Conditioning Of Finite Element Equations With Arbitrary Nonuniform Meshes
1051 - Asymptotic Stability of a Decomposed Compact Method for Highly Oscillatory Wave Problems
1052 - The Method Of Fictitious Time Integration And Approximate Fundamental Solutions For Nonlinear Elliptic PDEs
1053 - Numerical Methods for Option Pricing in Regime-Switching Jump Diffusion Models

EIT 319: Operator Splitting Methods For Numerical PDEs And Their Applications

Organizers: Shan Zhao, Qin Sheng
Speakers: Lili Ju, Wenyuan Liao, Chuan Li, Qin Sheng

1054 - Efficient and Stable Exponential Time Differencing Runge-Kutta Methods for Phase Field Elastic Bending Energy Models
1055 - An ADI preconditioner for solving discrete Helmholtz equation
1056 - Improvements On A Matched Interface And Boundary (MIB) Method For Solving Parabolic Interface Problems
1057 - The Legacy Of ADI And LOD Methods And Their Application In Solving Highly Oscillatory Wave Problems

Conference Schedule

Saturday, October 1, 2016

(Location: EIT and ETAS Buildings for Parallel Sessions)

Parallel Sessions | 1:30 p.m. - 3:10 p.m.

Session Abstracts on pages 20-27

EIT 321: Modeling and Computations for General and Chaotic Biological Systems

Organizers: Majid Bani-Yaghoub, Naveen K. Vaidya, Xianping Li, Noah Rhee
Speakers: Noah Rhee, Peter Uhl, Minh Nguyen, Jiu Ding

1058 - Biological Systems And Chaos
1059 - Some Properties Of A One Parameter Family Of Solutions To The Inverse Frobenius- Perron Problem
1060 - Monotone Traveling Waves In A General Discrete Model For Populations
1061 - A Picewise Linear Maximum Entropy Method for Invariant Measures of Random Maps

EIT 323: Applied and Computational Topology

Organizers: Henry Adams, Patrick Shipman
Speakers: Michael Lesnick, Matthew Wright, Mateusz Juda, Leyda Almodóvar Velázquez

1062 - Interactive Visualization of 2-D Persistence Modules
1063 - Computing Multidimensional Persistent Homology
1064 - Combinatorial Multivector Fields
1065 - Hclust Barcodes

EIT 325: Interactions Among Analysis, Optimization And Network Science

Organizers: Pietro Poggi-Corradini, Nathan Albin
Speakers: Pietro Poggi-Corradini, Mario Bonk, Brian Benson, David Aristoff, Nathan Albin

1066 - The Probabilistic Interpretation Of 2-Modulus On Networks
1067 - Discretizations And Analytic Structure
1068 - Curvature of Discrete Graphs
1069 - Structure Of Large Graphs With Constraints
1070 - Spanning Tree Modulus: Homogeneous Graphs and Deflation

ETAS 229: Recent Advances in Fractional PDEs

Organizers: Yanzhi Zhang
Speakers: Janna Lierl, Pablo Stinga, Zhu Wang, Nan Jiang, Yong Zhang

1071 - Boundary Harnack Principle For Nonsymmetric Stable-Like Operators On Smooth Open Sets
1072 - Extension Problem For Fractional Powers Of Parabolic Operators And Applications
1073 - POD Reduced-Order Modeling of Time-Fractional Partial Differential Equations with Applications in Parameter Identification
1074 - A Fractional Laplacian-Based Closure Model for Turbulent Fluid Flows
1075 - On The Ground States And Dynamics Of Space Fractional Nonlinear Schro¨Dinger/Gross-Pitaevskii Equations With Rotation Term And Nonlocal Nonlinear Interactions

ETAS 230: Numerical Approximation And Analysis For Time Dependent PDEs

Organizer: Cheng Wang, Steve Wise
Speaker order: Amanda Diegel, Yulong Xing, Fei Yu, Jue Yan

1076 - A Second Order in Time Finite Element Scheme for the Cahn-Hilliard-Navier-Stokes Equations
1077 - High Order Finite Volume WENO Methods For The Euler Equations With Gravitation
1078 - High Order Diffuse-Domain Methods for Partial Differential Equations in Complex Geometries
1079 - Fourier Type Error Analysis On The Solution Gradient's Super Convergence Of Direct DG Methods

ETAS 480: Some Novel Computational Methods For PDEs

Organizers: Huiqing Zhu
Speakers: Sheng-Wei Chi, Balaram KhatriGhimire, Jun Liu, Sheldon Wang, Daniel Waston

1080 - High Order Gradient Reproducing Kernel Collocation Method for Phase Field Fracture Model
1081 - Hybrid Chebyshev Polynomial Scheme For The Numerical Solution Of Elliptic PDEs
1082 - Multilevel Discretize-then-Optimize Algorithms for PDE-Constrained Optimizations
1083 - Mixed Finite Element Formulations and Resonance Frequency Predictions for Acoustoelastic Fluid-Structure Interactions
1084 - A Matrix Decomposition RBF Differential Quadrature Algorithm for Solving Elliptic Boundary Value Problems

ETAS 483: Recent Advance on High Order Numerical Methods for Partial Differential Equations

Organizers: Yuan Liu, Yingda Cheng
Speakers: Weitao Chen, Yingda Cheng, Huijing Du, Wei Guo

1085 - Semi-Implicit Integration Factor Methods On Sparse Grids For High-Dimensional Systems
1086 - An Adaptive Multiresoluton Discontinuous Galerkin Method for Time-Dependent Transport Equations in Multi-dimensions
1087 - Multiscale Computational Models of Complex Biological Systems
1088 - An Asymptotic Preserving Maxwell Solver Resulting in the Darwin Limit of Electrodynamics

Conference Schedule
Saturday, October 1, 2016

AFTERNOON SCHEDULE

3:50 p.m. - 5:30 p.m.
Parallel Sessions
EIT and ETAS Buildings
See full schedule on right,

6:30 p.m. - 8:00 p.m.
Banquet
Donaghey Student Center

Parallel Sessions | 3:50 p.m. - 5:30 p.m.

EIT 219: Mesh Adaption for Numerical Simulations

Organizers: Xianping Li, Weizhang Huang
Speakers: Runchang Lin, Cuong Ngo, Brandon Reyes, Dongmi Luo, Xianping Li

1089 - A Discontinuous Galerkin Least-Squares Finite Element Method For Solving Coupled Singularly Perturbed Reaction-Diffusion Equations
1090 - An Adaptive Moving Mesh Numerical Solution To The Porous Medium Equation
1091 - An Efficient Power-Aware Algorithm For A Class Of Stochastic Models
1092 - A Moving Mesh Discontinuous Galerkin Method For Hyperbolic Conservation Laws
1093 - Anisotropic Mesh Adaptation For Image Scaling

EIT 224: Partial Differential Equations: Analysis, Computation, Modeling, and Applications

Organizers: John Singler, Weiwei Hu
Speakers: Jiahong Wu, Wenqing Hu, Yang Yang, Walter Rusin

1094 - The Two-Dimensional Boussinesq Equations With Partial Or Fractional Dissipation
1095 - On 2-D Incompressible Euler Equations With Partial Damping
1096 - Thermo-Acoustic Tomography With Reflectors
1097 - Localized Anisotropic Regularity Conditions For The Navier-Stokes Equations

EIT 318: Highly Accurate and Effective Numerical Methods for Partial Differential Equations

Organizers: Qin Sheng, Abdul Q.M. Khaliq, JaEun Ku
Speakers: JaEun Ku, Songming Hou, Qin Sheng, Wenyuan Liao

1098 - Hybrid Finite Element Methods
1099 - Improved Imaging Methods for Extended Targets
2000 - An Asymptotic Stability of an Eikonal Splitting Method for Solving Paraxial Helmholtz Equations on Arbitrary Transverse Grids
2001 - An Accurate Numerical Method For Solving 3D Elastic Equation Using Helmholtz Decomposition

EIT 319: Operator Splitting Methods For Numerical PDEs And Their Applications

Organizers: Shan Zhao, Qin Sheng
Speakers: Shan Zhao, Alexey Sukhinin, Xinfeng Liu, JaEun Ku, Cheng Wang

2002 - Fast Operator Splitting Algorithms For The Electrostatic Analysis Of Solvated Biomolecules
2003 - Spatio-Temporal Modeling of Two-Color Filamentation
2004 - Integration Factor Methods For A Class Of High Order Differential Equations
2005 - An Efficient Solver For A System Of Finite Element Methods For Flux Variable
2006 - A Second Order Operator Splitting Numerical Scheme For The ``Good" Boussinesq Equation And Its Convergence Analysis

Conference Schedule

Saturday, October 1, 2016

(Location: EIT and ETAS Buildings for Parallel Sessions)

Parallel Sessions | 3:50 p.m. - 5:30 p.m.

Session Abstracts on pages 27-33

EIT 321: Modeling and Computations for General and Chaotic Biological Systems

Organizers: Majid Bani-Yaghoub, Naveen K. Vaidya, Xianping Li, Noah Rhee
Speakers: Naveen Vaidya, Libin Rong, Songnian Zhao, Maia Martcheva

2007 - Modeling Movements Of HIV In Vaginal Mucus
2008 - Modeling Viral Control by CD8+ T Cells
2009 - Optimal Control in Transmission Dynamics of Zoonotic Visceral Leishmaniasis
2010 - Structural And Practical Identifiability Issues Of Immuno-Epidemiological Vector-Host Model

EIT 323: Applied and Computational Topology

Organizers: Henry Adams, Patrick Shipman
Speakers: Francis Motta, Hamza Ghadyali, Chad Giusti, Henry Adams

2011 - A Zoo Of Data And Questions
2012 - Topological Patterns in Climatic Data
2013 - Topological Methods In Neuroscience
2014 - The Theory Of Vietoris-Rips Complexes: What Is Known And What Is Open?

EIT 325: Interactions Among Analysis, Optimization and Network Science

Organizers: Pietro Poggi-Corradini, Nathan Albin
Speakers: Nages Shanmugalingam, Lukas Geyer, Michael Higgins, Caterina Scoglio, Daniela Ferrero

2015 - Uniformly Perfect Cantor Sets And Analysis On Trees
2016 - Conformal Dimension Of Sierpinski Carpets
2017 - Threshold Partitioning Problems and Applications in Statistics
2018 - Network-Centric Partner Notification Strategies to Contain Epidemics
2019 - Lower Bounds For The Power Domination Number Of A Graph

ETAS 229: Recent Developments of High Order Numerical Methods

Organizer: Ying Wang
Speaker order: Mustafa Aggul, Dilek Erkmen, Ming-jun Lai, S. Lakshmivarahan

2020 - High Accuracy Approach To Turbulence Modeling
2021 - Defect-Deferred Correction Method For The Two-Domain Convection-Dominated Convection-Diffusion Problem
2022 - Bivariate Spline Solution of Reaction-Diffusion Equations and Its Application
2023 - On The Structure Of Energy Conserving Low-Order Models

ETAS 230: Recent Developments in Discontinuous Galerkin Methods for Partial Differential Equations

Organizer: Mahboub Baccouch
Speakers: Yang Yang, Mahboub Baccouch, Bo Dong, Yulong Xing

2024 - Superconvergence Of Discontinuous Galerkin Methods For Nonlinear Hyperbolic Equations
2025 - \emph{A posteriori} error analysis of the discontinuous Galerkin method for two-dimensional linear hyperbolic conservation laws on Cartesian grids
2026 - Superconvergent HDG Methods For Third-Order Equations In One-Space Dimension
2027 - A Posteriori Error Estimates Of Local Discontinuous Galerkin Methods For The Generalized Korteweg-De Vries Equations

ETAS 480: Some Advances In Finite Element Methods

Organizers: Yuchuan Chu, Feng Shi
Speaker order: Feng Shi, Xiaozhe Hu, Ju Ming, Yuchuan Chu, Keyu Gong

2028 - A space-time discretization method for solving flow problems based on the partition of unity and adaptivity strategy
2029- Weak Galerkin Finite Element Method for the Biot's Consolidation Model
2030 - Multi-Level Monte Carlo Finite Element Method for A Stochastic Optimal Control Problem
2031 - A Dynamic Interface Immersed-Finite-Element Particle-In-Cell Method For Modeling Plasma-Wall Interactions
2032 - A Modified Weighting Algorithm for Immersed Finite Element Particle-In-Cell (IFE-PIC) Method

ETAS 483: Recent Advance on High Order Numerical Methods for Partial Differential Equations

Organizers: Yuan Liu, Yingda Cheng
Speakers: Yang Jiang, Qi Tang, He Yang, Yuan Liu

2033 - A WENO-based Method of Lines Transpose Approach for Vlasov Simulations
2034 - An Added-Mass/Added-Damping Partitioned Algorithm For Rigid Bodies And Incompressible Flows
2035 - Local Discontinuous Galerkin Methods for Khokhlov-Zabolotskaya-Kuznetzov Equation
2036 - A Simple Bound-Preserving Sweeping Technique For Conservative Numerical Approximations

Conference Schedule

Sunday October 2, 2016

(Location: EIT and ETAS Buildings for Parallel Sessions)

MORNING SCHEDULE

8:00 a.m. – Noon
Registration Desk Open
Coffee Station
EIT Building

8:30 a.m. - 10:10 a.m.
Parallel Sessions
EIT and ETAS Buildings
See full schedule on right

10:10 a.m. - 10:40 a.m.
Refreshment Break

10:40 a.m. - 12:20 p.m.
Parallel Sessions
EIT and ETAS Buildings
See full schedule on page 12

12:20 p.m.
Meeting Adjourns

Parallel Sessions | 8:30 a.m. - 10:10 a.m.

EIT 219: Mesh Adaption for Numerical Simulations

Organizers: Xianping Li, Weizhang Huang
Speakers: Stefano Micheletti, Cuiyu He, Avary Kolasinski, Junbo Cheng, Fei Zhang

2037 - Anisotropic mesh adaptation for crack propagation in brittle materials
2038 - Improved ZZ A Posterior Error Estimation For Diffusion Problem
2039 - A New Functional For Variational Mesh Generation And Adaption Based On Equidistribution And Alignment Conditions
2040 - A Four-Rarefaction Approximate Riemann Solver With Elastic Wave And Von Mises' Yielding Condition For Two-Dimension Elastic-Plastic Flows
2041 - A Moving Mesh Method For The Numerical Simulation Of Fracture Propagation

EIT 224: Partial Differential Equations: Analysis, Computation, Modeling, and Applications

Organizers: John Singler, Weiwei Hu
Speakers: Michael Schmidt, Siwei Duo, Hans-Werner van Wyk, Yangwen Zhang

2042 - Novel Lagrangian Methods for Imperfectly Mixed Chemical Reactions
2043 - Numerical Methods For Solving The Fractional Schrodinger Equation
2044 - Spatial Adaptivity For Numerical PDEs In The Presence Of Parametric Uncertainty
2045 - Group Finite Element Method For 2D And 3D Navier-Stokes And Boussinesq Equations

EIT 318: Methods Of Applied And Numerical Complex Analysis

Organizers: Anna Zemlyanova, Thomas DeLillo
Speakers: Anna Zemlyanova, Yuri Antipov, Aditi Ghosh

2046 - Two-Dimensional Fluid Flows Around Multiple Cylinders In The Presence Of Vortices
2047 - A Crack Induced By A Thin Rigid Inclusion Partly Debonded From The Matrix
2048 - A Fast Fourier Recursive Relation Method To Evaluate Singular Integrals In A Complex Plane

EIT 319: Nonlinear Analysis

Organizer: Matt Insall
Speakers: Giles Auchmuty, Shibin Dai, Youngjoon Hong, Ning Ju, Matt Insall

2049 - Nonlinear Boundary Value Problems for Harmonic Functions
2050 - Phase-Field Free Energy and Boundary Force for Molecular Solvation
2051 - Theoretical And Numerical Analysis Of Singularly Perturbed Problems
2052 - Solution Regularity for the Primitive Equations
2053 - Advances in the Mathematical Analysis of the Complete Iterative Inversion Method

EIT 321: Modeling and Computations for General and Chaotic Biological Systems

Organizers: Majid Bani-Yaghoub, Naveen K. Vaidya, Xianping Li, Noah Rhee
Speakers: Majid Bani-Yaghoub, James Moore, Jin Wang, Joe Tien

2054 - Optimal Control Policies For Reducing Johne's Disease In Dairy Farms
2055 - Modeling the Acceleration and Delay of Type 1 Diabetes by Viral Infection
2056 - Modeling Cholera In Heterogeneous Environments
2057 - Modeling The Trade-Off Between Transmission And Contact In Disease Dynamics

Conference Schedule

Sunday, October 2, 2016

(Location: EIT and ETAS Buildings for Parallel Sessions)

Parallel Sessions | 8:30 a.m. - 10:10 a.m.

Session Abstracts on pages 33-39

EIT 323: Applied and Computational Topology

Organizers: Henry Adams, Patrick Shipman
Speakers: Rachel Neville, Patrick Shipman, Pawel Dlotko, David Letscher

2058 - Topological Measure of Order on Lattice Patterns
2059 - The Soft Mode Plays A Role In Defect Persistence In Pattern-Forming Systems
2060 - Computational topology and computational electromagnetism
2061 - Persistent Homotopy: An Overview

EIT 325: Interactions Among Analysis, Optimization And Network Science

(Special Time 8:05 a.m. - 10:10 a.m.)

Organizers: Pietro Poggi-Corradini, Nathan Albin
Speakers: Jason Clemens, Jim Gill, Thiwanka Fernando, Hrant Hakobyan, Paul Horn

2062 - Blocker Duality for Modulus
2063 - Modulus and Spaces Without Walks
2064 - An Investigation Of Node-Based Metrics On Networks Arising From P-Modulus
2065 - Quasisymmetric Embeddings Of Metric Spaces
2065A - A Hamilton Type Gradient Estimate For Solutions To The Heat Equation On Graphs

ETAS 229: Recent Developments of High Order Numerical Methods

Organizer: Ying Wang
Speaker order: Songting Luo, Lin Mu, Jin-song Pei, Ran Zhang

2066 - High-Order Methods For Traveltime And Amplitude In Fast Huygens Sweeping Method For High Frequency Helmholtz Equation
2067 - Weak Galerkin Finite Element Methods and Implementations
2068 - A Brief Introduction to “Mem-Models” in Engineering Mechanics Applications
2069 - Maximum Principles For P1-P0 Weak Galerkin Finite Element Approximations Of Quasi-Linear Second Order Elliptic Equations

ETAS 230: Recent Developments in Discontinuous Galerkin Methods for Partial Differential Equations

Organizer: Mahboub Baccouch
Speakers: Joshua Buli, Ari Stern, James Rossmanith, Bahaudin Hashmi

2070 - A Local Discontinuous Galerkin Method for the Coupled BBM-BBM System
2071 - Multisymplectic HDG methods
2072 - High-order DG-FEM for Micro-Macro Partitioned Kinetic Models
2073 - Modeling of Important Vapor-to-Particle Reactions

ETAS 480: Some Advances in Finite Element Methods

Organizers: Yuchuan Chu, Feng Shi
Speaker order: Fatma Songul Ozesenli Tetikoglu, Lulu Quan, Fatih Sabahattin Tetikoglu, Yingwei Wang

2074 - Numerical Solution of an Elliptic-Hyperbolic Equation with an Unknown Parameter
2075 - Time-domain Immersed Finite Element Methods for Electromagnetic Scattering and Radiation in Composite Material
2076 - The positivity of the difference operator with periodic conditions and its application
2077 - Muntz-Galerkin Methods And Applications To Mixed Dirichlet-Neumann Boundary Value Problems

ETAS 483: Contributed presentations

Speakers: Adelaide Akers, Dennis Brewer, Rong Fan, S. Lakshmivarahan, Hung Le

2078 - Existence and Symmetry of Small-amplitude Solitary Water Waves with Discontinuous Vorticity
2079 - An Introductory Course in Partial Differential Equations Using Mathematica
2080 - A Squared Correlation Coefficient of the Correlation Matrix
2081 - Data Ming, Data Assimilation and Prediction - Parts of a Continuum
2082 - The Transmission Problem for Elliptic Equations with Wentzel Boundary Condition

Conference Schedule

Sunday October 2, 2016

(Location: EIT and ETAS Buildings for Parallel Sessions)

MORNING SCHEDULE

8:00 a.m. – Noon
Registration Desk Open
Coffee Station
EIT Building

8:30 a.m. - 10:10 a.m.
Parallel Sessions
EIT and ETAS Buildings
See full schedule on pages 10-11

Session Abstracts on pages 39-42

10:10 a.m. - 10:40 a.m.
Refreshment Break

10:40 a.m. - 12:20 p.m.
Parallel Sessions
EIT and ETAS Buildings
See full schedule on right

12:20 p.m.
Meeting Adjourns

Parallel Sessions | 10:40 a.m. - 12:20 p.m.

EIT 219, 224, 229, 230, 480, 483: No scheduled talks

EIT 318: Methods Of Applied And Numerical Complex Analysis

Organizers: Anna Zemlyanova, Thomas DeLillo
Speakers: Tom DeLillo, Justin Mears, Mehran Mehrabi

2083 - A Comparison of Some Numerical Conformal Mapping Methods for Simply and Multiply Connected Domains
2084 - Computation of Stokes Waves Using Conformal Mapping
2085 - Analytical Analysis of Gas Diffusion into Noncircular Pores of Shale Organic Matter

EIT 319: Contributed talks

Speakers: Lasanthi Pelawa Watagoda, Liangya Pi, Changxin Qiu, Hasthika Rupasinghe Arachchige Don

2086 - Inference After Variable Selection
2087 - An Investigation on the Data Assimilation with Kalman Filter and Finite Elements for Subsurface Flows
2088 - A Multi-Physics Domain Decomposition Method for Navier-Stokes-Darcy Model
2089 - Bootstrapping Analogs of the Two Sample Hotelling's T^2 Test}

EIT 321: Modeling and Computations for General and Chaotic Biological Systems

Organizers: Majid Bani-Yaghoub, Naveen K. Vaidya, Xianping Li, Noah Rhee
Speakers: Xianping Li, Weijiu Liu, Gayla Olbricht, Yi Sun

2090 - Mathematical Modeling and Computation of Spatio-temporal Dynamics of Dengue Epidemics
2091 - Asymptotic Tracking and Disturbance Rejection of the Blood Glucose Regulation System
2092 - Modeling Sleep Patterns In The Fruit Fly To Investigate The Link Between Sleep And Alzheimer's Disease
2093 - Kinetic Monte Carlo Simulations of Multicellular Aggregate Self-Assembly in Biofabrication

EIT 323: Applied and Computational Topology

Organizers: Henry Adams, Patrick Shipman
Speakers: Amit Patel, Lori Ziegelmeier, Isabel Darcy, Iuliana Oprea

2094 - Semicontinuity of Persistence Diagrams
2095 - Persistent Homology on Grassmann Manifolds for Analysis of Hyperspectral Movies
2096 - Studying Knots Via Heat Maps
2097 - Topological Measures of Snow Surface Roughness

EIT 325: Interactions Among Analysis, Optimization And Network Science

Organizers: Pietro Poggi-Corradini, Nathan Albin
Speakers: Dominique Zosso, Lizaveta Ihnatsyeva, Heman Shakeri, Kevin Wildrick

2098 - Primal-Dual Methods for p-Modulus on Graphs
2099 - Functions Of Fractional Smoothness On Metric Measure Spaces
3000 - Analyzing Loop Structures In Networks
3001 - Metric Spaces of Small Cotype

Conference Plenary Speakers

Friday, September 30, 2016

9:20 a.m. - 10:10 a.m.

Irene Gamba

University of Texas-Austin

Conservative Solvers for Collisional Kinetic Boltzmann and Landau-Poisson Systems

ABSTRACT: These computational models are at the core of collisional plasma theories. In particular we will discuss several aspects of conservative solvers for the kinetic transport equations of particle interactions that involve either linear or non-linear Boltzmann as well as the non-linear Landau equations, by means of stagger conservative DG schemes for the transport part and DG or spectral solvers for the collisional part, linked by a projection method that is conservative. In addition we will discuss the computational aspects of boundary layer formation due to rough boundary effects for insulating conditions.

9:20 a.m. - 10:10 a.m.

Weizhang Huang

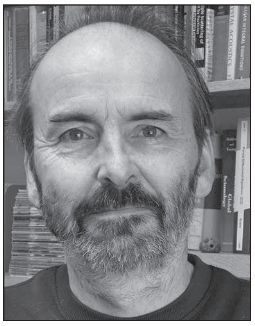
University of Kansas

A New Implementation of the MMPDE Moving Mesh Method and Applications

ABSTRACT: The MMPDE moving mesh method is a dynamic mesh adaptation method for use in the numerical solution of partial differential equations. It employs a partial differential equation (MMPDE) to move the mesh nodes continuously in time and orderly in space while adapting to evolving features in the solution of the underlying problem. The MMPDE is formulated as the gradient flow equation of a meshing functional that is typically designed based on geometric, physical, and/or accuracy considerations. In this talk, I will describe a new discretization of the MMPDE which gives the mesh velocities explicitly, analytically, and in a compact matrix form. The discretization leads to a simple, efficient, and robust implementation of the MMPDE method. In particular, it works for convex or nonconvex domains and is guaranteed to produce nonsingular meshes. Some applications of the method will be discussed, including mesh smoothing (to improve mesh quality), generation of anisotropic polygonal meshes, and the numerical solution of the porous medium equation and the regularized long-wave equation.

Conference Plenary Speakers

Saturday, October 1, 2016

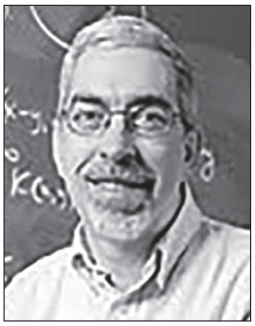


9:20 a.m. - 10:10 a.m.

Paul Martin
Colorado School of Mines

Solving the Wave Equation: Acoustic Scattering in the Time Domain

ABSTRACT: Transient acoustic waves are generated or scattered by an obstacle. This leads to initial-boundary value problems for the wave equation. Recent studies usually assume that solutions are smooth. However, many interesting physical problems lead to non-smooth solutions: there are moving wavefronts. These situations are usually handled by seeking weak solutions, but care is needed to ensure that constraints imposed by the underlying continuum mechanics are respected. We investigate some of the consequences, with a focus on the benchmark problem of scattering by a sphere.



10:40 a.m. - 11:40 a.m.

Robert Pego
Carnegie Mellon University

Euler Sprays and Optimal Transportation

ABSTRACT: We describe a striking connection between Arnold's least-action principle for incompressible Euler flows and geodesic paths for Wasserstein distance. A connection with a variant of Brenier's relaxed least-action principle for generalized Euler flows will be outlined also. This is joint work with Jian-Guo Liu and Dejan Slepcev.

Friday, September 30, 2016
1:30 p.m. - 3:10 p.m.

EIT 219: Recent Advances on Numerical Methods for Interface Problems

Organizers: Xu Zhang, James B. Collins
Speakers: Long Chen, Jeb Collins, Tao Lin, Cuiyu He, Songming Hou

1001 - An Interface-Fitted Mesh Generator And Virtual Element Methods For Elliptic Interface Problems

Long Chen, University of California at Irvine

In this work, we develop a simple and efficient interface-fitted mesh algorithm which can produce an interface-fitted mesh in two and three dimension quickly. Elements in such interface-fitted mesh are not restricted to simplex but can be polygons or polyhedron. We thus apply Virtual Element Methods to solve the elliptic interface problem in two and three dimensions. We present some numerical results to illustrate the effectiveness of our method and prove an optimal order convergence of our method. This is a joint work with Huayi Wei and Min Wen.

1002 - A Posteriori Error Estimation For A Cut Cell Method With Uncertain Interface Location

Jeb Collins, West Texas A&M University

We study a simple diffusive process in which the diffusivity is discontinuous across an interface interior to the domain. In many situations, the location of the interface is measured at a small number of locations and these measurements contain error. Thus the location of the interface and the solution itself are subject to uncertainty. A Monte Carlo approach is employed which requires solving a large number of sample problems, each with a different interface location. An efficient adjoint-based a posteriori technique is used to estimate the error in a quantity of interest for each sample problem. This error has a component due to the numerical approximation of the diffusive process and a component arising from the uncertainty in the interface location. A recognition of these separate sources of error is necessary in order to construct effective adaptivity strategies.

1003 - Applications of Immersed Finite Element Methods

Tao Lin, Department of Mathematics, Virginia Tech

Interface problems often appear in numerical simulations over domains consisting of multiple materials leading to discontinuous coefficients in the involved partial differential equations whose solutions are inevitably less smooth around the material interfaces. This presentation will start from a brief description of recently developed immersed finite element (IFE) methods that can use a Cartesian mesh to solve interface problems even with non-trivial interface geometry. We will then present a few application problems to demonstrate where IFE methods can be advantageous. The presentation will conclude with a few research topics in IFE methods.

1004 -A Posteriori error estimation for nonconforming finite element methods

Cuiyu He, Purdue University

In this talk, we derive and analysis a robust residual-based A Posteriori error estimation without the Quasi-monotone assumption for nonconforming FEM on interface problems whose diffusion coefficients could possibly possess large jumps across interfaces. Using a new and more direct approach, we derive a new residual-based error estimator for CR element that can be proved both robustly reliable and efficient in the sense that both constants are indecent of the ratio of the jump of diffusion coefficients. Numerical results are also provided.

1005 - Numerical Methods For Solving Linear And Nonlinear Interface Problems

Songming Hou, Louisiana Tech University

We present numerical methods for solving linear and nonlinear interface problems. The key idea of these methods is to use different basis functions for test and trial functions and to use non-body-fitted grids.

EIT 224: Partial Differential Equations: Analysis, Computation, Modeling, and Applications

Organizers: John Singler, Weiwei Hu
Speakers: Tong Li, Mathew Johnson, Samuel Walsh, Aslihan Demirkaya, Majid Bani-Yaghoub

1006 - Global Wellposedness And Traveling Waves To The PDE Models Of Chemotaxis

Tong Li, University of Iowa

We investigate global existence and long time behavior of solutions for PDE models of chemotaxis. These models include the classical Keller-Segel model and its variations such as a model reflecting rotational chemotactic motion. Moreover, we establish the existence and the nonlinear stability of large-amplitude traveling wave solutions to the system of nonlinear conservation laws derived from Keller-Segel model.

1007 - Dynamics and Stability of Viscous Roll Waves

Mathew Johnson, University of Kansas

Roll waves are well observed hydrodynamic instabilities occurring in inclined thin film flow, occurring from the competition of gravitational forces pulling the fluid down the ramp and the frictional forces exerted on the fluid along the surface of the ramp. Although the observation of roll waves is a common experience (I'll try to convince you of this!), and while a great deal of effort has been devoted to studying these waves experimentally, numerically, and through formal calculations, a complete mathematical understanding of the existence of such structures that are "physically observable", in the sense that they persist when subject to small perturbations, is still lacking. In this talk, I will discuss recent progress in this direction. This is joint work with Blake Barker (Brown), Pascal Noble (University of Toulouse), L. Miguel Rodrigues (University of Rennes), and Kevin Zumbrun (Indiana University)

1008 - Existence And Qualitative Theory Of Stratified Solitary Water Waves

Samuel Walsh, University of Missouri, Columbia

In this talk, we will report some recent results concerning two-dimensional gravity solitary water waves with hereogeneous density. The fluid domain is assumed be bounded below by an impenetrable flat ocean bed, while the interface between the water and vacuum above is a free boundary. Our main existence result states that, for any smooth choice of upstream velocity and streamline density function, there exists a path connected set of such solutions that includes large-amplitude surface waves. Indeed, this solution set can be continued up to (but does not include) an ``extreme wave`` that possess a stagnation point. We will also discuss a number of results characterizing the qualitative features of solitary stratified waves. In part, these include bounds on the Froude number from above and below that are new even for constant density flow; an a priori bound on the velocity field and lower bound on the pressure; a proof of the nonexistence of monotone bores for stratified surface waves; and a theorem ensuring that all supercritical solitary waves of elevation have an axis of even symmetry. This is joint work with R. M. Chen and M. H. Wheeler.

1009 - Numerical Results On Existence And Stability Of Standing And Traveling Waves For The Fourth Order Beam Equation

Aslihan Demirkaya, University of Hartford

In this work, we study numerically the existence and stability of some special solutions of the nonlinear beam equation: $u_{tt}+u_{xxxx}+u-|u|^{p-1} u=0$ when $p=3$ and $p=5$. For the standing wave solutions $u(x,t)=e^{i\omega t}\varphi_{\omega}(x)$ we numerically illustrate their existence using variational approach. Our numerics illustrate the existence of both ground states and exited states. We also compute numerically the threshold value ω^* which separates stable and unstable ground states. Next, we study the existence and linear stability of periodic traveling wave solutions $u(x,t)=\varphi(x+ct)$. We present numerical illustration of the theoretically predicted threshold value of the speed c which separates the stable and unstable waves.

1010 - Stability Of Travelling And Stationary Waves Arising From A Delayed Hyperbolic–Parabolic Population Model

Majid Bani-Yaghoub, University of Missouri-Kansas City

We consider a hyperbolic–parabolic population model which takes into account the time lag in spread of invasive species. In the absence of time lag, the model is reduced to a parabolic equation, whose traveling and stationary wave solutions have been extensively studied. Using the perturbation methods, when the time lag is sufficiently small, we show that the stability of wave solutions of the hyperbolic-parabolic model and the reduced model are concurrent. Furthermore, formation of the traveling and stationary wave solutions of the hyperbolic-parabolic model to the wave solutions is numerically explored for different time lag values.

EIT 318: Highly Accurate and Effective Numerical Methods for Partial Differential Equations

Organizers: Qin Sheng, Abdul Q.M. Khaliq, JaEun Ku
Speakers: Aaron Benham, Matthew Beauregard, Nick Kosmatov, Josh Padgett

1011 - Multiple Positive Solutions Of A Semipositone Fourth-Order Boundary Value Problem

Aaron Benham, University of Arkansas at Little Rock

We consider a nonlinear fourth-order boundary value problem. Our method is based on a cone-theoretic method which is used to obtain existence and multiplicity results which improve those in several previously published papers.

1012 - A Nonlinear Splitting Algorithm for Systems of Partial Differential Equations with self-Diffusion

Matthew A. Beauregard, Stephen F. Austin State University

Systems of reaction-diffusion equations are commonly used in biological models of food chains. The populations and their complicated interactions present numerous challenges in theory and in numerical approximation. In particular, self-diffusion is a nonlinear term that models over-crowding of a particular species. The nonlinearity complicates attempts to construct efficient and accurate numerical approximations of the underlying systems of equations. In this talk, a new nonlinear splitting algorithm is designed for a partial differential equation that incorporates self-diffusion. We present a general model that incorporates self-diffusion and develop a numerical approximation. The numerical analysis of the approximation provides criteria for stability and convergence. Numerical examples are used to illustrate the theoretical results.

1013 - The Sturm-Liouville Boundary Value Problem With Impulsive Effects On The Half-Line

Nickolai Kosmatov, University of Arkansas at Little Rock

Using a cone-theoretic theorem, we obtain the existence of positive solutions of the semipositone Sturm-Liouville boundary value problem on the half-line subject to nonlinear functional impulsive conditions.

1014 - Solving The Degenerate Stochastic Kawarada Equation Via An Adaptive Crank-Nicolson Method

Josh Padgett, Baylor University

This talk concerns the use of a nonuniform finite difference method for solving a degenerate Kawarada quenching-combustion equation with a vibrant stochastic source term. Arbitrary grids are introduced in both space and time to accommodate the uncertainty and singularities involved. It is shown that under proper constraints on mesh step sizes, the positivity and monotonicity of the solution are maintained. The numerical stability of the scheme is studied in the classical von Neumann sense by freezing the nonlinear source term and then the analysis is further improved by including the contributions of the source term. Numerical experiments are given to illustrate our conclusions and further explore the possible effects of the stochastic term on solution profile and quenching times.

EIT 319: No Talks Scheduled

EIT 321: No Talks Scheduled

EIT 323: Applied and Computational Topology

Organizers: Henry Adams, Patrick Shipman
Speakers: Eric Hanson, Jose Perea, Douglas Heisterkamp, Sara Kalisnik

1015 - Persistence Images: Representing Persistent Homology for Machine Learning

Eric Hanson, Texas Christian University

If we consider a data set as a noisy sampling of an underlying topological space, then the tools of topological data analysis (TDA) can be used to understand the structure of the data. One of these tools is persistent homology (PH), which provides a multiscale description of the homological features, often represented by a persistence diagram (PD). A desire to analyze data using the homological features captured by PH, in combination with machine learning (ML) techniques, has led to numerous approaches to adapting the PD representation for this purpose. Certainly, the space of PDs can be given a metric structure, but often additional structure is valuable to machine learning tasks. We convert a PD to a finite-dimensional vector representation, and prove the stability of this transformation with respect to small perturbations in the inputs. This talk will begin with an introduction to PH, describe this new representation, which we call a persistence image, and discuss how it can be used with ML techniques.

1016 - Directional Features, Projective Coordinates and Classification

Jose Perea, Michigan State University

Directional features in images have been shown to be fundamental in digit recognition and texture classification tasks. We will show in this talk how projective spaces can be used to model distributions of said features, and how data can be mapped onto these spaces.

1017 - Thin Position Inspired Algorithms For Machine Learning And Data Analysis

Douglas Heisterkamp, Oklahoma State University

This presentation introduces the algorithms of topologically intrinsic lexicographic ordering (TILO), pinch ratio clustering (PRC), and thin tree position (TTP) which are inspired by thin position for knots and 3-dimensional manifolds. An overview will be given of the benefits and limitations of applying the algorithms to clustering, feature selection, manifold learning, and data visualization.

1018 - Tropical Coordinates on the Space of Persistence Barcodes

Sara Kalisnik Verovsek, Brown University

In the last two decades applied topologists have developed numerous methods for 'measuring' and building combinatorial representations of the shape of the data. The most famous example of the former is persistent homology. This adaptation of classical homology assigns a barcode, i.e. a collection of intervals with endpoints on the real line, to a finite metric space. Unfortunately, barcodes are not well-adapted for use by practitioners in machine learning tasks. We can circumvent this problem by assigning numerical quantities to barcodes and these outputs can then be used as input to standard algorithms. I will talk about max-plus polynomials and tropical rational functions that can be used as coordinates on the space of barcodes. All of these are stable with respect to the standard distance functions (bottleneck, Wasserstein) used on the barcode space.

EIT 325: New Numerical Advances on Wave Propagation Problems

Organizer: Yassine Boubendir
Speakers: Yassine Boubendir, Lise-Marie Imbert-Gerard, Wangtao Lu

1019 - Asymptotic Expansions of the Helmholtz Equation Solutions in the Case of Convex Obstacles

Yassine Boubendir, New Jersey Institute of Technology

In this talk, we will review some of the well-known asymptotic expansions of solutions of the Helmholtz equation. Then, we will present some new expansions based on local approximations of the Dirichlet to Neumann operator. The goal is the derivation of appropriate ansatz that can be used in the design of high-frequency integral equation solvers.

1020 - Volume Integral Methods For Wave Propagation In Inhomogeneous Media

Lise-Marie Imbert-Gerard, NYU

We will discuss high order accurate numerical methods for scattering by a penetrable obstacle in an homogeneous background. In the penetrable case, as opposed to obstacle scattering case, a volume integral formulation is required. The volume integral equation corresponding to the Helmholtz equation is called the Lippmann-Schwinger equation. It is derived by representing the scattered field as the convolution of the background Green's function for the exterior homogeneous medium with an unknown density. We developed an automatically adaptive, high-order accurate discretization method that provides rapid access to arbitrary elements of the system matrix. This method relies on the identification of two different regimes of interactions with respect to the singularity of the Green's function. The system itself is solved using a hierarchical fast direct solver (HODLR), by constructing a compressed version of the inverse matrix. Applications to waves in plasmas will be described. Radio frequency waves are used to heat and probe plasmas. Time harmonic equations model these waves, with variable coefficients depending of the plasma density. Our numerical method is particularly convenient to study the influence of the incident angle : the compression of the inverse matrix is performed only once independently of the incident angle.

1021 - Babich-Like Ansatz For Three-Dimensional Point-Source Maxwell's Equations In An Inhomogeneous Medium At High Frequencies

Wangtao Lu, Michigan State University

We propose a novel Babich-like ansatz consisting of an infinite series of dyadic coefficients (three-by-three matrices) and spherical Hankel functions for solving point-source Maxwell's equations in an inhomogeneous medium so as to produce the so-called dyadic Green's function. Using properties of spherical Hankel functions, we derive governing equations for the unknown asymptotics of the ansatz including the traveltime function and dyadic coefficients. By proposing matching conditions at the point source, we rigorously derive asymptotic behaviors of these geometrical-optics ingredients near the source so that their initial data at the source point are well-defined. To verify the feasibility of the proposed ansatz, we truncate the ansatz to keep only the first two terms, and we further develop partial-differential-equation based Eulerian approaches to compute the resulting asymptotic solutions. Since the system of governing equations for each dyadic coefficient is strongly coupled, we introduce auxiliary variables to transform these strongly coupled systems into decoupled scalar equations. Furthermore, we develop high-order Lax-Friedrichs weighted essentially non-oscillatory schemes for computing these auxiliary variables so that the Green's function can be constructed. Numerical examples demonstrate that our new ansatz yields a uniform asymptotic solution in the region of space containing a point source but no other caustics. This is a joint work with Jianliang Qian and Robert Burridge.

ETAS 229: Recent Advances in Fractional PDEs

Organizer: Yanzhi Zhang
Speakers: Hong Wang, Mohsen Zayernouri, Xiaofan Li, Joseph E. Pasciak, Siwei Duo

1022 - A Fast Numerical Method for a Bond-Based Linear Peridynamic Model

Hong Wang, University of South Carolina

We develop a fast numerical method for a two-dimensional bond-based linear peridynamic model, which provides an appropriate description of the planar deformation of a continuous elastic body involving discontinuities or other singularities. The method reduces the computational cost of evaluating and assembling the stiffness matrix from $O(N^2)$ to $O(N)$, where N is the number of unknowns in the discrete system. The method also reduces the computational work from O(N^2) to O(N log N) and the memory requirement from O(N^2) to O(N). All of this is achieved by carefully exploring the structure of the stiffness matrix of the collocation scheme, without any lossy compression involved.

1023 - Unified Petrov-Galerkin Spectral Methods for High-Dimensional FPDEs

Mohsen Zayernouri, Michigan State University

We present a series of unified spectral methods of Petrov-Galerkin sense for a general class of linear fractional partial differential equations (FPDEs) in any $(d+1)$ dimensions, $d\geq 1$. To efficiently solve the corresponding linear systems, we also develop a unified fast solver with optimal complexity. The proposed scheme works with the same ease and efficiency for parabolic, elliptic, and hyperbolic problems.

1024 - Numerical Schemes For Integro-Differential Equations Related To Alpha-Stable Processes

Xiaofan Li, Illinois Institute of Technology

The mean first exit time, escape probability and transitional probability density are utilized to quantify dynamical behaviors of stochastic differential equations with non-Gaussian, α-stable type L\'evy motions. Taking advantage of the Toeplitz matrix structure of the time-space discretization, a fast and accurate numerical algorithm is proposed to simulate the nonlocal Fokker-Planck equations on either a bounded or infinite domain. Under a specified condition, the scheme is shown to satisfy a discrete maximum principle and to be convergent. The numerical results for two prototypical stochastic systems, the Ornstein-Uhlenbeck system and the double-well system are shown.

1025 - Numerical Approximation of a Variational Problem on a Bounded Domain involving the Fractional Laplacian

Joseph Pasciak, Texas A&M University

The mathematical theory and numerical analysis of non-local operators has been a topic of intensive research in recent years. One class of applications come from replacing Brownian motion diffusion by diffusion coming from a symmetric α-stable Levy process, i.e., the Laplace operator is replaced by a fractional Laplacian. In this talk, we propose a numerical approximation of equations with this type of diffusion terms posed on bounded domains. We focus on the simplest example of an elliptic variational problem coming from the fractional Laplacian on a bounded domain with homogeneous Dirichlet boundary conditions. Although it is conceptually feasible to study the Galerkin approximation based on a standard finite element space, such a direct approach is not viable as the exact computation of the resulting stiffness matrix entries is not possible (at least in two or more spatial dimensions). Instead, we will develop a non-conforming method by approximating the action of the stiffness matrix on a vector (sometimes referred to as a matrix free approach). The bilinear form is written as an improper integral involving the solution of parameter dependent elliptic problems on R^d. We compute an approximate action of stiffness matrix by applying a SINC quadrature rule to the improper integral, replacing the problems on R^d by problems on parameter dependent bounded domains, and the application of the finite element method to the bounded domain problems. The entire procedure can be implemented using standard finite element tools, e.g., the DEAL-II library. The analysis of the resulting algorithm is discussed. In addition, the results of numerical computations on a model problem with known solution are given.

1026 - A Fast Algorithm For Solving The Space-Time Fractional Diffusion Equation

Siwei Duo, Missouri University of Science and Technology

In this talk, we present a fast and accurate algorithm to solve the space-time fractional diffusion equation with spectral fractional Laplacian in space and Caputo fractional derivative in time. The central finite difference scheme combine with the matrix transfer technique is used for the space discretization, and the Laplace transform is used for time integration. Because of the nonlocality, numerical discretization of the spectral fractional Laplacian results in a large dense matrix, which causes considerable challenges in not only storing the matrix but also computing the matrix-vector products. By using the compact structure of the discrete system and the sine transform, our algorithm avoids to store the large matrix therefore significantly reduces the computational costs, especially in higher spatial dimensions. Varies numerical examples will be presented to demonstrate the accuracy and efficiency of the algorithm.

ETAS 230: Numerical Approximation And Analysis For Time Dependent PDEs

Organizers: Cheng Wang, Steve Wise
Speaker order: Cheng Wang, Wen-Qiang Feng, Zhen Guan, Lili Ju

1027 - Energy-Stable Pseudo-Spectral Numerical Scheme For The Cahn-Hilliard Equation And The Homogeneous Linear Iteration Algorithm

Cheng Wang, University of Massachusetts Dartmouth

A second order energy stable numerical scheme is presented for the two and three dimensional Cahn-Hilliard equation, with Fourier pseudo-spectral approximation in space. The convex splitting nature assures its unique solvability and unconditional energy stability. Meanwhile, the implicit treatment of the nonlinear term makes a direct nonlinear solver not available, due to the global nature of the pseudo-spectral spatial discretization. In turn, a linear iteration algorithm is proposed to overcome this difficulty, in which a Douglas-Dupont-type regularization term is introduced. As a consequence, the numerical efficiency has been greatly improved, since the highly nonlinear system can be decomposed as an iteration of purely linear solvers. Moreover, a careful nonlinear analysis shows a contraction mapping property of this linear iteration. A few numerical examples are also presented in this talk.

1028 - Efficient Finite-Difference Geometric Multigrid Solvers for the Cahn-Hilliard Equation

Wenqiang Feng, The University of Tennessee, Knoxville

We present two geometric multigrid solvers with finite difference discretization for the Cahn-Hilliard equation. One is preconditioned steepest descent with multigrid method as preconditioner and the other one is using multigrid method as a direct solver. In the preconditioned method, we minimize the corresponding convex energies with the proposed method in stead of solving the nonlinear system directly. Moreover, by using the energy dissipation property, we derive the discrete ℓ^p bound for the solution, as well as the upper-bound for the second derivative of the energy, and investigate the convergence properties. Various numerical simulations are carried out to demonstrate the efficiency and robustness of the proposed methods.

1029 - Unconditional Stable Method for the Amplitude Description of the Phase-Field Crystal model

Zhen Guan, University of California, Irvine

The amplitude description of the Phase-Field Crystal model is widely used coarse-grained approach for studying polycrystalline solidification. In addition to the obvious computational advantages over the atomistic models, the amplitude description allows for isolating variables associated with macroscopic description of continuum media such as order parameter or displacement fields. Here we present an unconditional energy stable method with parallelogram mesh. The resulting nonlinear scheme is handled by highly efficient nonlinear multigrid method.

1030 - Energy Stability and Error Estimates of Exponential Time Differencing Schemes for the Epitaxial Growth Model without Slope Selection

Lili Ju, University of South Carolina

In this talk, we present a class of exponential time differencing (ETD) schemes for solving the epitaxial growth model without slope selection. A linear convex splitting is first applied to the energy functional of the model, and then Fourier collocation and ETD-based multistep approximations are used respectively for spatial discretization and time integration of the corresponding gradient flow equation. Energy stabilities and error estimates of the first and second order ETD schemes are rigorously established in the fully discrete sense. We also numerically demonstrate the accuracy of the proposed schemes and simulate the coarsening dynamics with small diffusion coefficients. The results show the logarithm law for the energy decay and the power laws for growth of the surface roughness and the mound width, which are consistent with the existing theories in the literature.

ETAS 480: Some Novel Computational Methods For PDEs

Organizer: Huiqing Zhu

Speakers: Jiangguo Liu, Zhimin Zhang, Zhiyun Yu, Xinxiang Li, Huiqing Zhu

1031 - THex Algorithm and Its Applications in Finite Element Methods

Jiangguo Liu, Colorado State University

In this talk, we present the THex algorithm that refines a tetrahedral mesh into a hexahedral mesh. Based on this, we discuss finite element methods on hexahedral meshes.

1032 - Polynomial Preserving Recovery for Gradient and Hessian

Zhimin Zhang, Beijing Computational Science Research Center; Wayne State University

Post-processing techniques are important in scientific and engineering computation. One of such technique, Superconvergent Patch Recovery (SPR) proposed by Zienkiewicz-Zhu in 1992, has been widely used in finite element commercial software packages such as Abaqus, ANSYS, Diffpack, etc.; another one, Polynomial Preserving Recovery (PPR) has been adopted by COMSOL Multiphysics since 2008. In this talk, I will discuss some resent development of PPR in obtaining the Hessian matrix (second derivatives) from the computed data.

1033 - Nonconforming Mixed Finite Elements Method For The Three-Dimensional Incompressible Magnetohydrodynamics Equation

Zhiyun Yu, Zhongyuan University of Technology

Nonconforming mixed finite element method is established for the stationary incompressible magnetohydrodynamics equation which couples Navier-Stokes equations with Maxwell's equations in a bounded domain in 3D. The lowest order finite elements on tetrahedral or hexahedra are chosen to approximate the pressure, the velocity field and the magnetic field. The hydrodynamic unknowns are discretized by inf-sup stable finite element pairs and the magnetic field by H^1-conforming element and H(curl)-conforming element, respectively. Through applying the prior estimates of the exact and approximated solutions, and choosing the appropriate parameters Re, Rm and S in the MHD equation considered, we obtain the optimal order error estimates of H^1-norm and L^2-norm for the velocity field, L^2-norm for the pressure and the broken H^1-norm and H(curl)-norm for the magnetic field, respectively.

1034 - Superconvergence and Extrapolation of Quasi-Wilson Element for Nonsymmetric and Indefinite Problem

Xinxiang Li, Shanghai University

The quasi-Wilson finite element method will be discussed to pproximate the nonsymmetric and indefinite problem. Applying the characteristics of this element, the known high accuracy analysis results of bilinear element and averaging technique, the super-close property and global superconvergence result with O(h^2)order are obtained. Furthermore, a new asymptotic error expansion is deduced and the extrapolation solution with O(h^3) order is derived which is two order higher than the traditional error estimate.

1035 - Method Of Fundamental Solutions Using Transformed Angular Basis Functions

Huiqing Zhu, The University of Southern Mississippi

In this talk, we introduce transformed angular basis function-s(ABFs) that can be used in the method of fundamental solutions (MFS) as basis functions. The idea of ABF was proposed by Young et al. in 2015, but its implementation was limited by the selection of source points. By the transformation we designed, the source points can be selected in a similar way to traditional MFS using radial basis functions. Numerical experiments on solving interior and exterior potential potential flow problems governed by the 2-D Laplace equation will be presented.

ETAS 483: Contributed presentations

Speakers: Necmettin Aggez, Kyle Claassen, Tania Hazra, Michelle Maiden, Zhihan Wei

1036 - A Note on Finite Difference Method for NBVP of the Hyperbolic Type

Necmettin Aggez, Fatih University Allaberen Ashyralyev, Fatih University

In this work, the nonlocal boundary value problem for the semilinear hyperbolic equation in a Hilbert space is considered. The second order of accuracy difference scheme is presented for obtaining approximate solution of the nonlocal boundary value problem. The convergence estimate for the solution of this difference scheme is obtained. Theoretical results are supported by a numerical example.

1037 - Antiperiodic Ground State Theory for Fractional Schr\"odinger Operators

Kyle Claassen, University of Kansas;
Mathew Johnson (University of Kansas)

Schr\"odinger operators with periodic potentials acting on antiperiodic function spaces present special challenges, as the ground state eigenvalues of such operators need not be simple, and the corresponding eigen functions are not sign-definite. With an eye toward proving (orbital) stability of antiperiodic standing waves in a class of fractional nonlinear Schr\"odinger equations, we provide a general theory for characterizing the T-antiperiodic ground states of linear fractional Schr\"odinger operators having T-periodic potentials.

1038 - Stable Operator Splitting Method For Free Energy Calculations Of One Atom Model

Tania Hazra, Department of Mathematics, University of Alabama, Tuscaloosa, AL; Shan Zhao, Department of Mathematics, University of Alabama, Tuscaloosa, AL

The work explores the stability impact of the novel unconditionally stable operator splitting methods for solving the time dependent nonlinear Poisson-Boltzmann (NPB) equation for the electrostatic analysis of solvated biomolecules. In a pseudo-transient continuation solution of the NPB equation, the nonlinear term is analytically integrated, so that the difficulties in direct treatment of the strong nonlinearity can be bypassed. There are several methods to solve the NPB equations. We are interested in Alternating Direction Implicit (ADI) schemes and Locally-One Dimensional schemes (LOD). The ADI methods are known to be conditionally stable, although being fully implicit. On the other hand, LOD scheme is computationally less expensive and LOD scheme based on implicit Euler integration is more stable than ADI schemes. It has been observed that there is a noticeable difference between the linearized Poisson Boltzmann Equation result and ADI-based NPB results in steady state solutions. That motivated us to analyze the ADI schemes and later on LOD schemes to detect the factor for which the stability is getting affected.

1039 - Soliton Envelopes in Viscous Conduits

Michelle Maiden, University of Colorado Boulder;
Mark Hoefer, University of Colorado Boulder

Viscous fluid conduits provide an ideal system for the study of dissipationless, dispersive hydrodynamics. A dense, viscous fluid serves as the background medium through which a lighter, less viscous fluid buoyantly rises. If the interior fluid is continuously injected, a deformable pipe forms. The long wave interfacial dynamics are well-described by a dispersive nonlinear partial differential equation called the conduit equation. In this talk, numerical and asymptotic analysis as well as experiments of the viscous fluid conduit system will be presented. Of particular interest are modulations of periodic traveling wave solutions of the conduit equation. Approximate dark and bright envelope soliton solutions have been predicted and observed numerically to persist for long times; these are well approximated by a cubic Nonlinear Schrodinger equation in the weakly nonlinear regime, and move with the group velocity of linear waves to leading order. The bright envelope solitons move with negative velocity, so they are difficult to create in a viscous conduit that is controllable only at the bottom boundary. However, dark envelope solitons exhibit positive velocity, so they should be accessible in an experimental setup.

1040 - Three-Dimensional Matched Alternating Direction Implicit (ADI) Schemes for Solving the Heat Equation with Complex Interface

Zhihan Wei; Shan Zhao

The Douglas alternating direction implicit (ADI) method is a powerful finite difference method for solving parabolic equations, due to its unconditional stability and high efficiency. However, accuracy reduction is a serious issue for the interface problem with jumps on the interface and non-smooth solutions, especially for three-dimensional (3D) problems. If the jumps and its derivatives are given in a function along the interface, we propose a novel tensor product decomposition to decouple 3D jump conditions into essentially one-dimensional (1D) ones. Then, by combining with the matched interface and boundary (MIB) technique, the 1D conditions can be incorporated into the ADI central difference discretization. Fast algebraic solvers for perturbed tridiagonal systems are developed to maintain the computational efficiency. The proposed matched ADI approaches not only maintain both the unconditional stability property and the efficiency of Thomas algorithm, but also achieve spatially second order accuracy in resolving complex geometries due to the MIB technique.

Saturday, October 1, 2016

1:30 p.m. - 3:10 p.m.

EIT 219: Recent Advances on Numerical Methods for Interface Problems

Organizers: Xu Zhang, James B. Collins
Speakers: Xu Zhang, Marcus Sarkis, Xiaoming He, Ruchi Guo, Nishant Panda

1041 - Superconvergence of Immersed Finite Element Methods

Xu Zhang, Mississippi State University

Immersed finite element method (IFEM) is a class of finite element methods (FEM) that can solve interface problems with unfitted meshes. Superconvergence is a phenomenon that the order of convergence at certain points is higher than the maximum order of convergence of numerical solutions. In this talk, we introduce some superconvergence properties of IFEM for one dimensional interface problems. The key step in our analysis is constructing the so-called generalized orthogonal polynomials with discontinuous weight function. We will show that IFE functions perfectly fit into the framework of generalized orthogonal polynomials. Finally, we will demonstrate that IFE solutions inherit all desired superconvegence properties from standard FEM. In particular, on interface elements, superconvergence occurs at roots of generalized orthogonal polynomials.

1042 - Multiscale Variational FETI-DP Discretization For High-Contrast Problems

Marcus Sarkis, Worcester Polytecnic Institute

We combine the multiscale variational method and adaptativeFETI-DP preconditioner techniques to design and rigorous analyze discretizations for the Darcy's equations with high-contrast permeability. We establish a priori second-order error estimates with hidden constants independently of the permeability. This is a joint work with Prof. Alexandre Madureira from LNCC, Petropolis, Brazil.

1043 - Multi-Physics Domain Decomposition Method For Coupled Porous Media Flow And Free Flow

Xiaoming He, Missouri University of Science and Technology

The Navier-Stokes-Darcy and Stokes-Darcy models have attracted significant attention in the past fifteen years since it arises in many applications such as surface water flows, groundwater flows in karst aquifers, petroleum extraction and industrial filtration. It has higher fidelity than either the Darcy or Navier-Stokes systems on their own for the coupled flow problem. But coupling the two constituent models leads to a very complex system. This presentation discusses a multi-physics domain decomposition method for solving the Navier-Stokes-Darcy system. Convergence is demonstrated and computational results are presented to illustrate the features of the proposed method.

1044 - A Class of Immersed Finite Element Spaces Defined by the Actual Interface

Ruchi Guo, Virginia Tech

In this talk, we present a new class of immersed finite element (IFE) spaces defined by the actual interface for solving the second order elliptic interface problems on Cartesian meshes. Functions in these IFE spaces are locally piecewise polynomials and constructed with either linear polynomials, or bilinear polynomials, or rotate-Q1 polynomials, or Crouzeix-Raviart polynomials. We will discuss the unisolvence, boundedness and optimal approximation capability of these IFE spaces by a new unified framework.

1045 - Stochastic Inverse Problem For Internal Boundaries: A Measure Theoretic Solution

Nishant Panda, Colorado State University

In this talk, we present a measure theoretic framework to infer internal boundaries, the initial configuration of which is uncertain. This is a typical scenario in modeling geophysical quantities like flow through porous rocks, where distinct rock regions form an interface whose precise description is difficult to obtain. We first present an abstract model in which the random interface is parametrized in finite dimensions, for example piecewise linear, piecewise spline etc. Then, given a distribution on some observed quantity we determine a distribution on the parametrized interface. A partition of unity is then used to reconstruct the random interface.

EIT 224: Partial Differential Equations: Analysis, Computation, Modeling, and Applications

Organizers: John Singler, Weiwei Hu
Speakers: John Singler, Weiwei Hu, Taige Wang, Ning Ju

1046 - Model Reduction of a Nonlinear Cable-Mass PDE System with Dynamic Boundary Input

John Singler, Missouri University of Science and Technology

We perform balanced truncation model reduction of a nonlinear PDE system modeling the motion of a flexible cable attached to a mass-spring system at each end. The input to the system is the driving force to the mass-spring system at the left end, and the output of interest is the displacement and velocity of the mass at the right end. We present (1) theoretical results for the PDE system and (2) numerical results comparing the input-output response of the nonlinear PDE system and the nonlinear reduced order model.

1047 - Boundary Control for Optimal Mixing by Stokes Flows

Weiwei Hu, Oklahoma State University

We discuss the optimal boundary control problem for mixing an inhomogeneous distribution of a passive scalar field in an unsteady Stokes flow. The problem is motivated by mixing the fluids within a cavity or vessel at low Reynolds numbers by moving the walls or stirring at the boundaries. It is natural to consider the velocity field induced by a control input tangentially acting on the boundary of the domain through the Navier slip boundary conditions. Our main objective is to design an optimal Navier boundary control that optimizes mixing at a given final time. A rigorous proof of the existence of an optimal controller is presented and the first-order necessary conditions for optimality are derived.

1048 - A Thixotropic Flow Dynamics Under Large Amplitude Oscillatory Shearing

Taige Wang, Virginia Tech

The PEC (partially extending strand convection) model of Larson is able to describe thixotropic yield stress behavior in the limit where the relaxation time is large. In this talk, we discuss the dynamic behavior of the model under an imposed periodic shear force $\tau(t) = B\sin(\tau t)$. We identify regimes of fast, slow and yielded dynamics. The multiscale analysis turns out to be mathematically crucial for the analysis among the dynamics.

1049 - Global Regularity And Long-Time Behavior For The Solutions To 2D Boussinesq Equations

Ning Ju, Oklahoma State University

New results recently obtained by the speaker about global regularity and long-time behavior for solutions to 2D Boussinesq equations will be presented and discussed.

EIT 318: Highly Accurate and Effective Numerical Methods for Partial Differential Equations

Organizers: Qin Sheng, Abdul Q.M. Khaliq, JaEun Ku
Speakers: Weizhang Huang, Tiffany Jones, Haiyan Tian, Ruihua Liu

1050 - Conditioning Of Finite Element Equations With Arbitrary Nonuniform Meshes

Weizhang Huang, University of Kansas

Mesh adaptation has become an indispensable tool for use in the numerical solution of partial differential equations to improve computational accuracy and efficiency. However, mesh adaptation often leads to nonuniform meshes and their nonuniformity can have significant impacts on the conditioning and the efficient solution of the underlying algebraic systems. In this talk we will present some new results in the studies of those impacts for the finite element approximation of boundary value and initial-boundary value problems of linear diffusion equations.

1051 - Asymptotic Stability of a Decomposed Compact Method for Highly Oscillatory Wave Problems

Tiffany Jones, Baylor University

The paraxial Helmholtz equation describes the propogation of electromagnetic waves in the form of either paraboloidal waves or Gaussian beams. Becuase most lasers emit beams of this form, this equation is used frequently in beam propagation computations, particularly within focal regions. This paper concerns a decomposed compact scheme for solving a highly oscillatory paraxial Helmholtz problem with a large wave number in radially symmetric fields. We are particularly interested in decomposition schemes that are highly accurate in transverse directions as well as highly efficient and effective for practical applications. The decomposition is utilized in the transverse direction to eliminate the singularity of the differential equation in polar coordinates. Special attention is paid to the numerical stability of the proposed decomposition algorithm. It is shown that the numerical method introduced is proven to be stable in an asymptotic sense. The method is also highly accurate and efficient due to its straightforward algorithmic structure. Computational examples are presented to illustrate our conclusions.

1052 - The Method Of Fictitious Time Integration And Approximate Fundamental Solutions For Nonlinear Elliptic PDEs

Haiyan Tian, The University of Southern Mississippi

Through a fictitious time approach, a nonlinear elliptic-type PDE problem is converted into a time-dependent quasilinear problem. This is further approximated by a sequence of time-dependent linear nonhomogeneous modified Helmholtz boundary value problems, which are solved by the method of particular solutions of Delta-shaped basis functions and approximate fundamental solutions. Numerical results are provided to show the accuracy and validity of the computational method.

1053 - Numerical Methods for Option Pricing in Regime-Switching Jump Diffusion Models

Ruihua Liu, University of Dayton

This presentation is concerned with numerical methods for pricing options in regime-switching jump diffusion models. Option values are computed by solving a system of m coupled partial integro-differential equations (PIDE), where m>1 is the number of regimes considered for the market. We develop a tree method based on the probabilistic representation of the option values as an expectation of discounted payoff under a risk-neutral probability measure. The proposed trees grow linearly as the number of tree steps increases, and can be used for both European and American options. Numerical results are reported and compared with a finite-difference (FD) method.

EIT 319: Operator Splitting Methods For Numerical PDEs And Their Applications

Organizers: Shan Zhao, Qin Sheng
Speakers: Lili Ju, Wenyuan Liao, Chuan Li, Qin Sheng

1054 - Efficient and Stable Exponential Time Differencing Runge-Kutta Methods for Phase Field Elastic Bending Energy Models

Lili Ju, University of South Carolina

The Willmore flow formulated by phase field dynamics based on the elastic bending energy model has been widely used to describe the shape transformation of biological lipid vesicles. In this talk, we present some efficient and stable numerical methods for simulating the unconstrained phase fi eld Willmore dynamics and the phase fi eld Willmore dynamics with fixed volume and surface area constraints. The proposed methods can be high-order accurate and are completely explicit in nature, by combining exponential time differencing Runge-Kutta approximations for time integration with spectral discretizations for spatial operators on regular meshes. We also incorporate novel linear operator splitting techniques into the numerical schemes to improve the discrete energy stability. In order to avoid extra numerical instability brought by use of large penalty parameters in solving the constrained phase fi eld Willmore dynamics problem, a modified augmented Lagrange multiplier approach is proposed and adopted. Various numerical experiments are performed to demonstrate accuracy and stability of the proposed methods.

1055 - An ADI preconditioner for solving discrete Helmholtz equation

Wenyuan Liao, University of Calgary

Numerical solution of multi-dimensional Helmholtz equation with high wave number is a challenging computational task, mainly because of two reasons. First, due to the high wave number, it is required that the continuous Helmholtz equation should be discretized by a very fine grid, which leads to a huge linear algebraic system. It is even worse for the high wave number case, as a fixed number grid points per wavelength is required. The large size of the linear algebraic system makes it difficult to use direct method, in particular in higher-dimensional cases. Second, the discrete Helmholtz equation is a highly indefinite linear algebraic system which is extremely hard to be solved by classical iterative methods. For example, many classical iterative methods such as conjugate method converges slowly or not even converge. In this work an operator splitting technique is used to factorize the 2D or 3D Helmholtz equation into a sequence of 1D Helmholtz equations, which is then directly solved by efficient tridiagonal solver. This ADI solver is then used a preconditioner which is combined with the regular iterative methods to form an efficient preconditioned iterative method. Numerical experiments are conducted and numerical results are compared with other popular methods, which demonstrated that the new method is accurate, efficient and efficient in solving the Helmholtz equation with high wave number.

1056 - Improvements On A Matched Interface And Boundary (MIB) Method For Solving Parabolic Interface Problems

Chuan Li, West Chester University of Pennsylvania

Many computational biophysics applications can all be mathematically modeled as the parabolic interface problems. The standard numerical methods for solving partial differential equations (PDEs) often perform poorly for the parabolic interface problems due to the fact that the physical solutions are usually non-smooth or even discontinuous across the arbitrarily shaped interface of two media. In this talk, I will present our most recent work of developing of a matched interface and boundary (MIB) method in the direction of improving the scheme for handling more complex 2D geometries and interface conditions. This work is collaborated with Dr. Shan Zhao from the University of Alabama.

1057 - The Legacy Of ADI And LOD Methods And Their Application In Solving Highly Oscillatory Wave Problems

Qin Sheng, Baylor University

Different operator splitting methods have been playing an important role in computations of numerical solutions of partial differential equations. Modern numerical strategies including mesh adaptations, linear and nonlinear transformations are also utilized together with splitting algorithms in applications. This will be a brief survey talk for two cornerstones of the operator splitting, that is, Alternating Direction Implicit (ADI) and Local One-Dimensional (LOD) methods, as well as their applications together with an eikonal mapping for solving highly oscillatory paraxial optical wave equations in slowly varying envelope approximations of active laser beams. The resulted finite difference scheme is not only oscillation-free, but also asymptotically stable. This ensures the high efficiency and applicability in industrial applications.

EIT 321: Modeling and Computations for General and Chaotic Biological Systems

Organizers: Majid Bani-Yaghoub, Naveen K. Vaidya, Xianping Li, Noah Rhee
Speakers: Noah Rhee, Peter Uhl, Minh Nguyen, Jiu Ding

1058 - Biological Systems And Chaos

Noah Rhee, University of Missouri-Kansas City

In this paper, given a chaotic map, we show that Ulam's method generate a sequence of density functions in L^1-space that may converge weakly to a function in L^1-space. In such a case we show that the limiting function generates an absolutely continuous invariant measure. This fact can be used to analyze some biological systems that may exhibit chaotic behavior.

1059 - Some Properties Of A One Parameter Family Of Solutions To The Inverse Frobenius- Perron Problem

Peter Uhl, University of Missouri- Kansas City

In this paper we give a review of the Inverse Frobenius- Perron problem (IFPP) developed by Rogers et al: how to create chaotic maps with the desired piecewise constant invariant density. While this method provides infinitely many chaotic map solutions, we study three properties of one parameter family of chaotic map solutions. First, we show that the desired invariant density can be approximated by each truncated orbit generated from these solutions. Then we numerically develop the average error formula that depends on the parameter. We also show that individual errors are distributed normally. Second, we show that the fixed point iteration using the Frobenius- Perron operators associated with these solutions converge to the desired invariant density starting from any piecewise constant density and also show how the rate of convergence of the fixed point iteration depends on the parameter . Finally, we study the autocorrelation of each orbit generated by these solutions, and show how the autocorrelation with finite time lag depends on the parameter, and also present numerical simulations.

1060 - Monotone Traveling Waves In A General Discrete Model For Populations

Minh Nguyen, University of Arkansas at Little Rock

In this talk we consider the existence of monotone traveling waves for a class of general integral difference model for populations that allows the dispersal probability to have no continuous density functions but the fecundity functions to generate a monotone dynamical systems. In this setting we deal with the non-compactness of the evolution operator by using the monotone iteration method.

1061 - A Picewise Linear Maximum Entropy Method for Invariant Measures of Random Maps

Jiu Ding, The University of Southern Mississippi

We present a numerical method for the approximation of absolutely continuous invariant measures of one dimensional position dependent random maps, based on the maximum entropy principle and piecewise linear moment functions. Numerical results are presented to show the convergence of the method.

EIT 323: Applied and Computational Topology

Organizers: Henry Adams, Patrick Shipman
Speakers: Michael Lesnick, Matthew Wright, Mateusz Juda, Leyda Almodóvar Velázquez

1062 - Interactive Visualization of 2-D Persistence Modules

Michael Lesnick, Princeton University

Matthew Wright and I have designed a tool for the interactive visualization of 2-D persistent homology. In this talk, I'll discuss the mathematical foundations of this tool.

1063 - Computing Multidimensional Persistent Homology

Matthew Wright, St. Olaf College

Multidimensional persistent homology is highly relevant in applications that require the analysis of data which is simultaneously filtered by two or more parameters. However, the algebraic complexity of multidimensional persistence modules makes it difficult to extract useful invariants in this setting. In this talk, I will describe recent work with Mike Lesnick to efficiently compute and visualize both the bigraded Betti numbers and the rank invariant of two-dimensional persistence modules. I will focus on computational challenges and current work to overcome such obstacles.

1064 - Combinatorial Multivector Fields

Mateusz Juda, Jagiellonian University

In this talk we introduce theory, algorithms, and software for analysis of vector fields given by finite sample. We generalize combinatorial vector fields proposed by Forman. We show definitions of attractors, repellers, and Morse sets in combinatorial setting using Lefschetz complexes and partial orders. We show examples constructed by the algorithms for: flows given by differential equations, experimental data sets. In particular we show our recent application for diffusion tensor imaging (DTI) of the human brain.

1065 - Hclust Barcodes

Leyda Almodóvar Velázquez, Stonehill College

In persistent homology, a barcode keeps track of the birth and death of cycles. In the case of the H_0 barcode, if all 0-cycles are born at time 0 (which is usually the case when analyzing data), the H_0 barcode can be obtained from the single linkage hierarchical clustering dendrogram where the death time of a component corresponds to a merge point in the dendrogram. In a similar way, we can create hclust barcodes using any method of hierarchical clustering. We compare single, average, complete, and Ward's linkage hclust barcodes. This work was performed in collaboration with Isabel Darcy and Paul Samuel Ignacio.

EIT 325: Interactions Among Analysis, Optimization And Network Science

Organizers: Pietro Poggi-Corradini, Nathan Albin
Speakers: Pietro Poggi-Corradini, Mario Bonk, Brian Benson, David Aristoff, Nathan Albin

1066 - The Probabilistic Interpretation Of 2-Modulus On Networks

Pietro Poggi-Corradini, Kansas State University

I will present on overview of ongoing research being done by the NODE research group (https://node.math.ksu.edu/) at Kansas State University. The theory of modulus was originally developed in complex analysis and was then used to extend the notion of (quasi) conformal maps to higher dimensional real Euclidean spaces and, in fact, to abstract metric measure spaces. On networks, modulus provides a method for quantifying the richness of a family of objects. Some examples of families of objects that we have studied are: families of walks, families of spanning trees, families of simple loops, etc. Using convex duality, we have shown that modulus has a probabilistic interpretation. Namely, modulus tries to minimize the expected overlap among the objects in the family and as a result it spreads the expected edge-usage the family makes of each edge in the network.

1067 - Discretizations And Analytic Structure

Mario Bonk, UCLA

How much of the analytic structure of a metric space can be captured by its discrete approximations? In my talk I will discuss this problem in two related contexts, namely for

Sobolev functions on the space (joint work with E. Saksman) and for moduli of path families (work by J. Lindquist).

1068 - Curvature of Discrete Graphs

Brian Benson, Kansas State University

There are several approaches to interpreting the concept of curvature, as defined on a Riemannian manifold, on a discrete graph. In 1985, Bakry and Emery suggested an invariant on the graph based on a Markov semigroup. Specifically, this invariant replaces a bound on curvature for estimates on graphs which are analogues of those on manifolds. In 2007, Ollivier used a more geometric observation to define a notion of curvature on graphs which is not equivalent to that of Bakry-Emery. Ollivier's curvature is related to solving transport problems on the graph. I will discuss work in progress related to these topics which is joint with Peter Ralli and Prasad Tetali.

1069 - Structure Of Large Graphs With Constraints

David Aristoff, Colorado State University

We consider large graphs with a finite number of constraints on subgraph densities. What is the "most likely" structure of such graphs? The answer can be obtained by solving a certain variational problem. We conjecture that all solutions correspond to multipodal graphs -- that is, graphs in which the vertex set can be divided into finitely many groups, with a constant connection probability any two groups.

1070 - Spanning Tree Modulus: Homogeneous Graphs and Deflation

Nathan Albin, Kansas State University

The concept of modulus of curve families originated in the field of complex analysis as a conformally invariant way to describe the size of a family of curves. The natural extension to discrete graphs provides a method for describing the size of a family of objects on a graph. This notion of size is more expressive than simply counting the number of objects; it is also sensitive to individual object size and to the diversity of edge use within the family. This talk will focus on the modulus of the family of spanning trees on an unweighted, undirected graph. Through standard techniques of Lagrangian duality, the modulus problem can be shown to be equivalent to the problem of choosing a probability mass function (pmf) on the family of spanning trees that minimizes the expected overlap of two independently selected random trees. This view of the modulus problem leads to a Deflation Theorem, which describes the spanning tree modulus structure of a graph through a sequence of simple "subgraph deflation" steps, ultimately providing deeper insight into the optimal pmfs for the graph.

ETAS 229: Recent Advances in Fractional PDEs

Organizers: Yanzhi Zhang
Speakers: Janna Lierl, Pablo Stinga, Zhu Wang, Nan Jiang, Yong Zhang

1071 - Boundary Harnack Principle For Nonsymmetric Stable-Like Operators On Smooth Open Sets

Janna Lierl, University of Connecticut

Consider a nonsymmetric stable-like operator with jump intensities $\kappa(x,y)|x-y|^{-d-\alpha}$ for $x,y \in R^d$, where $\alpha \in (0,2)$. I will show that under mild assumptions on κ, a boundary Harnack principle holds on any $C^{1,1}$-open set D with explicit boundary decay rate dist$(\cdot,\partial D)^{\alpha/2}$.

1072 - Extension Problem For Fractional Powers Of Parabolic Operators And Applications

Pablo Raúl Stinga, Iowa State University

By using the semigroup language approach we show that the fractional powers of any uniformly parabolic operator with time-dependent coefficients can be realized as a Dirichlet-to-Neumann map through a parabolic extension problem in one more dimension. In particular, the fractional powers of the heat operator are considered. Using this characterization we obtain regularity estimates for nonlocal space-time equations, like the master equation from continuous time random walks, as the one considered by L. Caffarelli and L. Silvestre. These results are based on a joint work with J. L. Torrea. As a particular case, we recover the extension problem for the Marchaud fractional derivative, which was previously obtained in joint work with A. Bernardis, F. J. Martín-Reyes and J. L. Torrea

1073 - POD Reduced-Order Modeling of Time-Fractional Partial Differential Equations with Applications in Parameter Identification

Zhu Wang, University of South Carolina

In this paper, a reduced-order model (ROM) based on the proper orthogonal decomposition (POD) method is proposed for efficiently simulating time-fractional partial differential equations (TFPDEs). We demonstrate the effectiveness of the POD-ROM by several numerical examples, in which the ROM achieves the same accuracy of the full-order model (FOM) over a long-term simulation while greatly reducing the computational cost. The proposed ROM is then regarded as a surrogate of FOM and is applied to an inverse problem for identifying the order of the time-fractional derivative of the TFPDE model. Based on the Levenberg--Marquardt regularization iterative method with the Armijo rule, we develop a ROM-based algorithm for solving the inverse problem. For cases in which the observation data is either uncontaminated or contaminated by random noise, the proposed approach is able to achieve accurate parameter estimation efficiently.

1074 - A Fractional Laplacian-Based Closure Model for Turbulent Fluid Flows

Nan Jiang, Missouri University of Science and Technology

Nonlocal Models have attracted intensive research interests in recent years due to their ability to model phenomena that can not be correctly described by classical local PDE models. In particular, fractional derivative models have been found to be very effective in modeling anomalous diffusion processes. In this talk, we will present a new closure model based on the fractional Laplacian operator that accounts for the anomalous diffusion that arises in fully-developed turbulent fluid flows. Both theoretical aspect of the turbulence model and the numerical algorithms to implement the model will be discussed.

1075 - On The Ground States And Dynamics Of Space Fractional Nonlinear Schro¨Dinger/Gross-Pitaevskii Equations With Rotation Term And Nonlocal Nonlinear Interactions

Yong Zhang, IRMAR, University of Rennes 1, France

In this paper, we propose some efficient and robust numerical methods to compute the ground states and dynamics of Fractional Schrodinger Equation (FSE) with a rotation term and nonlocal nonlinear interactions. In particular, a newly developed Gaussian-sum (GauSum) solver is used for the nonlocal interaction evaluation [31]. To compute the ground states, we integrate the preconditioned Krylov subspace pseudo- spectral method [4] and the GauSum solver. For the dynamics simulation, using the rotating Lagrangian coordinates transform [14], we first reformulate the FSE into a new equation without rotation. Then, a time-splitting pseudo-spectral scheme incorporated with the GauSum solver is proposed to simulate the new FSE. In parallel to the numerical schemes, we also prove some existence and nonexistence results for the ground states. Dynamical laws of some standard quantities, including the mass, energy, angular momentum and the center of mass, are stated. The ground states properties with respect to the fractional order and/or rotating frequencies, dynamics involving decoherence and turbulence together with some interesting phenomena are reported.

ETAS 230: Numerical Approximation And Analysis For Time Dependent PDEs

Organizer: Cheng Wang, Steve Wise
Speaker order: Amanda Diegel, Yulong Xing, Fei Yu, Jue Yan

1076 - A Second Order in Time Finite Element Scheme for the Cahn-Hilliard-Navier-Stokes Equations

Amanda Diegel, Louisiana State University

In this talk, we present a second order in time mixed finite element method for the Cahn-Hilliard equation coupled with a Navier-Stokes flow that models phase separation and coupled fluid flow in immiscible binary fluids in two and three dimensions. We will discuss the main results of the numerical scheme including the following. We show that our scheme is unconditionally energy stable with respect to a spatially discrete analogue of the continuous free energy of the system. Additionally, we show that the discrete phase variable is bounded in L^\infty(0,T;L^2) and the discrete chemical potential is bounded in L^\infty(0,T;L^2), for any time and space step sizes, in two and three dimensions, and for any finite final time T. We subsequently prove that these variables converge with optimal rates in the appropriate energy norms in both two and three dimensions. Hydrodynamical evolution in a gravitational field arises in many astrophysical and atmospheric problems. Improper treatment of the gravitational force can lead to a solution which oscillates around the equilibrium. In this presentation, we propose a recently developed well-balanced finite volume WENO method for the Euler equations under gravitational fields, which can maintain the isothermal and polytropic hydrostatic equilibrium states exactly. Some numerical tests are performed to verify the well-balanced property, high-order accuracy, and good resolution for smooth and discontinuous solutions.

1077 - High Order Finite Volume WENO Methods For The Euler Equations With Gravitation

Yulong Xing, University of California Riverside

Hydrodynamical evolution in a gravitational field arises in many astrophysical and atmospheric problems. Improper treatment of the gravitational force can lead to a solution which oscillates around the equilibrium. In this presentation, we propose a recently developed well-balanced finite volume WENO method for the Euler equations under gravitational fields, which can maintain the isothermal and polytropic hydrostatic equilibrium states exactly. Some numerical tests are performed to verify the well-balanced property, high-order accuracy, and good resolution for smooth and discontinuous solutions.

1078 - High Order Diffuse-Domain Methods for Partial Differential Equations in Complex Geometries

Fei Yu, University of California, Irvine

Recently, Li et al. (Comm. Math. Sci., 7:81-107, 2009) developed a diffuse domain method (DDM) in order to solve partial differential equations (PDE) on complex geometries. .In this approach the complex geometry was embedded into a larger, regular domain. The original PDE was reformulated with a phase field function, which smoothly approximates the characteristic function of the original domain, plus additional source terms that approximate the boundary conditions. Later Lerv{\aa}g and Lowengrub (Comm. Math. Sci., 2014) performed a matched asymptotic analysis of general diffuse domain methods for Neumann and Robin boundary conditions and showed that for certain choices of boundary condition approximations the DDM is second-order accurate in \(\epsilon\), which characterizes the width of the region over which the characteristic function is smoothed. We extend this analysis to PDEs with Dirichlet boundary conditions and show that by perturbing the reformulated equation in a certain way, we are able to achieve second-order accuracy in \(\epsilon\). Our analytic results are confirmed numerically in the \(L^2\) norm for selected test cases.

1079 - Fourier Type Error Analysis On The Solution Gradient's Super Convergence Of Direct DG Methods

Jue Yan, Iowa State University

Different to [1] [2] and [3], we develop direct discontinuous Galerkin method with interface correction(DDGIC) and symmetric DDG methods to directly solve chemotaxis Keller-Segel equations. Numerically we observe no order loss and obtain optimal convergence with P^k polynomial approximations. The reason behind is that DDGIC and symmetric DDG methods have the hidden super convergence property on the solution's gradient. With Fourier analysis technique, we prove the polynomial solution's spatial derivative is super convergent to the exact solutions spatial derivative in the weak sense or in some momentum sense. The super convergence property is not observed with the classical SIPG method. [1] Yekaterina Epshteyn and Alexander Kurganov. New interior penalty discontinuous Galerkin methods for the Keller-Segel chemotaxis model. SIAM J. Numer. Anal., 47(1):386–408, 2008/09. [2] Yekaterina Epshteyn, Discontinuous Galerkin methods for the chemotaxis and haptotaxis models. J. Comput. Appl. Math., 224(1):168–181, 2009. [3] Shu-C.-W. Li, X. H. and Y. Yang. Local discontinuous Galerkin methods for the Keller-Segel chemotaxis model.

ETAS 480: Some Novel Computational Methods For PDEs

Organizers: Huiqing Zhu
Speakers: Sheng-Wei Chi, Balaram KhatriGhimire, Jun Liu, Sheldon Wang, Daniel Waston

1080 - High Order Gradient Reproducing Kernel Collocation Method for Phase Field Fracture Model

Sheng-Wei Chi, University of Illinois at Chicago

The Reproducing Kernel approximation in conjunction with the Collocation Method (RKCM) was introduced for solutions of PDEs and engineering problems for some time. Although it offers only algebraic convergence, being less sensitive to the nodal distribution and of compact structure, thus better conditioning, make it an attractive method for engineering applications. However, taking direct derivatives of the reproducing kernel approximation is computationally expensive, in comparison to other commonly used approximations for collocation methods, such as RBFs. In this work, we address the high computational cost in the RKCM while achieving optimal convergence by adopting gradient reproduction kernel approximations for all derivatives involved in a PDE. In contrast to the earlier work, both first order and second order derivatives involved in the approximation for a second order PDE are expressed by gradient reproducing kernels in the present method, termed High order Gradient Reproducing Kernel Method (HG-RKCM). We show that the same number of collocation points and source points can be used in the HG-RKCM for optimal convergence. The numerical studies show that the present method is roughly 10 times faster than the RKCM. The method is applied to fracture modeling based on the phase field model.

1081 - Hybrid Chebyshev Polynomial Scheme For The Numerical Solution Of Elliptic PDEs

Balaram KhatriGhimire, Delta State University

In this talk, we propose hybrid Chebyshev polynomial scheme (HCPS), which combines two matrix systems of Chebyshev polynomial scheme into a single matrix system. This hybrid formulation requires solving only one system of equations and opens up the possibilities of solving large class of partial differential equations (PDEs). We consider problems governed by the Poisson equation and the inhomogeneous Cauchy-Navier equations. The solution is approximated by the sum of particular solution and homogeneous solution. Chebyshev polynomials are used to approximate a particular solution of a PDE. The Laplacian or biharmonic operator is kept on the left hand side and all the other terms are moved to the right hand side and treated as a forcing term. Numerical results show that our approach is highly accurate and stable.

1082 - Multilevel Discretize-then-Optimize Algorithms for PDE-Constrained Optimizations

Jun Liu, Jackson State University

In this talk, we first review some multigrid/multilevel algorithms that have been proposed for solving discretized optimization (or optimal control) problems governed by PDEs, in particular within the context of \textit{discretize-then-optimize} approach. Some numerical comparison and new perspectives will be presented. Moreover, to illustrate an interesting counter-intuitive phenomenon, an inconsistent discretization based on Simpson's rule for the objective functional will be discussed. Numerically, the observed convergence failure can be recovered by adding a suitable H1 regularization/penalty term with very little extra costs.

1083 - Mixed Finite Element Formulations and Resonance Frequency Predictions for Acoustoelastic Fluid-Structure Interactions

Sheldon (Xiaodong) Wang, Midwestern State University

It is very important to have a reliable finite element formulation for the prediction of resonance frequencies within fluid-solid interaction systems in which compressibility for both fluid and solid media as well as their interactions are important. In this work, we review two mixed finite element formulations proven to be reliable for this type of systems and relate them to transient analysis data from which the resonance frequency might be reconstructed with model reduction techniques. The incentive of this seemingly opposite approach is to utilize existing computational fluid dynamics (CFD) and finite element method (FEM) packages in engineering practice and to provide guidance on the importance of accurate prediction of resonance frequency in turbulent induced sound production for example vocal tracks. We also explore the effects of noise on these predictions.

1084 - A Matrix Decomposition RBF Differential Quadrature Algorithm for Solving Elliptic Boundary Value Problems

Daniel Watson, University of Southern MIssissippi

This talk discusses a differential quadrature (DQ)-radial basis function (RBF) method for the numerical solution of elliptic boundary value problems in circular domains. With an appropriate selection of collocation points, for any choice of RBF, the matrices in the systems appearing in this discretization possess block circulant structures. These linear systems can thus be solved efficiently using matrix decomposition algorithms (MDAs) and fast Fourier transforms (FFTs). In particular, we consider problems governed by the Poisson equation, the inhomogeneous biharmonic equation and the inhomogeneous Cauchy-Navier equations of elasticity. In addition to its simplicity, the proposed method can both achieve high accuracy and solve large-scale problems. The feasibility of the proposed techniques is illustrated by several numerical examples.

ETAS 483: Recent Advance on High Order Numerical Methods for Partial Differential Equations

Organizers: Yuan Liu, Yingda Cheng
Speakers: Weitao Chen, Yingda Cheng, Huijing Du, Wei Guo

1085 - Semi-Implicit Integration Factor Methods On Sparse Grids For High-Dimensional Systems

Weitao Chen, Department of Math, University of California, Irvine

Numerical methods for partial differential equations in high-dimensional spaces are often limited by the curse of dimensionality. Though the sparse grid technique, based on a one-dimensional hierarchical basis through tensor products, is popular for handling challenges such as those associated with spatial discretization, the stability conditions on time step size due to temporal discretization, such as those associated with high-order derivatives in space and stiff reactions, remain. Here, we incorporate the sparse grids with the implicit integration factor method (IIF) that is advantageous in terms of stability conditions for systems containing stiff reactions and diffusions. We combine IIF, in which the reaction is treated implicitly and the diffusion is treated explicitly and exactly, with various sparse grid techniques based on the finite element and finite difference methods and a multi-level combination approach. The overall method is found to be efficient in terms of both storage and computational time for solving a wide range of PDEs in high dimensions. In particular, the IIF with the sparse grid combination technique is flexible and effective in solving systems that may include cross-derivatives and non-constant diffusion coefficients. Extensive numerical simulations in both linear and nonlinear systems in high dimensions, along with applications of diffusive logistic equations and Fokker-Planck equations, demonstrate the accuracy, efficiency, and robustness of the new methods, indicating potential broad applications of the sparse grid-based integration factor method.

1086 - An Adaptive Multiresoluton Discontinuous Galerkin Method for Time-Dependent Transport Equations in Multi-dimensions

Yingda Cheng, Michigan State University

In this talk, we present an adaptive multiresolution DG method for time-dependent transport equations. The scheme is constructed based on the standard weak form of DG method for hyperbolic equations and the multiwavelets of Alpert. We show that our scheme can naturally go back to a sparse grid DG method, saving computational cost, when the solution possess sufficient smoothness. When the solution is no longer smooth, the adaptive algorithm that uses the hierarchical surplus as the refinement or coarsening indicator, can automatically capture the local structures. We use the Hash table as the underlying data structure and can deal with equations in arbitrary dimensions. By using the DG framework, many nice properties are retained for the transport equations. The numerical scheme is validated by benchmark tests with smooth and nonsmooth solutions, and the standard Vlasov-Poisson (VP) system and oscillatory VP system.

1087 - Multiscale Computational Models of Complex Biological Systems

Huijing Du, University of Nebraska, Lincoln

Computational biology is concerned with the modeling and simulation of biological phenomena, processes and systems. A large number of discrete and continuous models have made remarkable progresses for the description of subcellular systems, physiological dynamics, developmental and population biology. Almost always, these traditional models are focused on single biological scales. As the need for a detailed mechanistic understanding of biological function grows, the single-scale limitation of conventional models is no longer adequate. To setup an approach spanning multiple levels of biophysical reality, I will describe a new 3D hybrid framework which includes three major submodels: the discrete stochastic Subcellular Element Model for individual cellular activity; continuum reaction-diffusion-advection partial differential equations of extracellular biomolecules; a stochastic decision-making model for cell lineage transition. Our results demonstrate how a modeling approach coupling biologically relevant scales can provide new insights into the complex biological problems related to intestinal crypt structure, embryonic development and epidermal tissue regeneration.

1088 - An Asymptotic Preserving Maxwell Solver Resulting in the Darwin Limit of Electrodynamics

Wei Guo, Michigan State University

In plasma simulations, where the speed of light divided by a characteristic length is at a much higher frequency than other relevant parameters in the underlying system, such as the plasma frequency, implicit methods begin to play an important role in generating efficient solutions in these multi-scale problems. Under conditions of scale separation, one can rescale Maxwell's equations in such a way as to give a magneto static limit known as the Darwin approximation of electromagnetics. In this talk, we present a new approach to solve Maxwell's equations based on a Method of Lines Transpose formulation, combined with a fast summation method with computational complexity O(NlogN), where N is the number of grid points. Under appropriate scaling, we show that the proposed schemes result in asymptotic preserving methods that can recover the Darwin limit of electrodynamics.

Saturday, October 1, 2016

3:50 p.m. - 5:30 p.m.

EIT 219: Mesh Adaption for Numerical Simulations

Organizers: Xianping Li, Weizhang Huang
Speakers: Runchang Lin, Cuong Ngo, Brandon Reyes, Dongmi Luo, Xianping Li

1089 - A Discontinuous Galerkin Least-Squares Finite Element Method For Solving Coupled Singularly Perturbed Reaction-Diffusion Equations

Runchang Lin, Texas A&M International University

A discontinuous Galerkin least-squares finite element method is proposed to solve coupled reaction-diffusion equations with singular perturbations. This method produces solutions without numerical oscillations when uniform meshes are used. Numerical examples are provided to demonstrate the efficiency of the method.

1090 - An Adaptive Moving Mesh Numerical Solution To The Porous Medium Equation

Cuong Ngo, The University of Kansas

We present an adaptive moving mesh method for a numerical solution to the porous medium equation with and without variable exponents and absorption. It is based on the moving mesh partial differential equation approach, and shows a first-order convergence for uniform and arclength-based adaptive meshes and a second-order convergence for Hessian-based adaptive meshes. The method is applicable for solutions where the free boundaries have complex shapes and behaviors, and also for porous medium equations with variable exponents and absorption. Numerical results in two dimensions will be presented.

1091 - An Efficient Power-Aware Algorithm For A Class Of Stochastic Models

Brandon Reyes, Colorado School of Mines

We consider a class of partial differential equation models with non-deterministic parameters and develop an efficient parallel algorithm to compute, analyze, and quantify uncertainties in stochastic quantities of interest (QoI) induced by the parameters dependent model. In addition to implementing the parallel multilevel Monte Carlo based algorithm, we analyze the associated power consumption while running the parallel code on a cluster of high-performance computing nodes and hence develop efficient power-aware strategies for simulating the QoI.

1092 - A Moving Mesh Discontinuous Galerkin Method For Hyperbolic Conservation Laws

Dongmi Luo, Xiamen University

A moving mesh discontinuous Galerkin method is developed for the numerical solution of hyperbolic conservation laws. The method is a combination of the discontinuous Galerkin method and the mesh movement strategy which is based on the moving mesh partial differential equation approach and moves the mesh continuously in time and orderly in space using a system of mesh partial differential equations. It not only can achieve the high order in smooth regions, but also capture shocks well in nonsmooth regions. For the same number of grid points, the numerical solution with the moving mesh method is much better than ones with the uniform mesh method. Numerical examples are presented to show the accuracy and shock-capturing features of the method.

1093 - Anisotropic Mesh Adaptation For Image Scaling

Xianping Li, University of Missouri-Kansas City

We present the results using anisotropic mesh adaptation in image scaling. A 2D image is represented by an anisotropic triangular mesh. Then the image information on the mesh is saved in a compressed file (encoding). The image can be reconstructed (decoding) to any desired scale. Linear and higher order finite element interpolation methods are investigated for image reconstruction. The results show that anisotropic mesh adaptation provides good quality for image scaling, especially for upscaling.

EIT 224: Partial Differential Equations: Analysis, Computation, Modeling, and Applications

Organizers: John Singler, Weiwei Hu
Speakers: Jiahong Wu, Wenqing Hu, Yang Yang, Walter Rusin

1094 - The Two-Dimensional Boussinesq Equations With Partial Or Fractional Dissipation

Jiahong Wu, Oklahoma State University

The Boussinesq equations concerned here model geophysical flows such as atmospheric fronts and ocean circulations. In addition, they play an important role in the study of Rayleigh-Benard convection. Mathematically the 2D Boussinesq equations serve as a lower-dimensional model of the 3D hydrodynamics equations. The global regularity problem on the 2D Boussinesq equations with partial or fractional dissipation has attracted considerable attention in the last few years. This talk presents recent developments in this direction. In particular, we detail the global regularity result on the 2D Boussinesq equations with vertical dissipation as well as some recent work on the 2D Boussinesq equations with general critical dissipation. If time permits, we will also briefly discuss the regularity problem on the partially dissipated Boussinesq equations in a bounded domain.

1095 - On 2-D Incompressible Euler Equations With Partial Damping

Wenqing Hu, Missouri University of Science and Technology

We consider various questions about the 2d incompressible Navier-Stokes and Euler equations on a torus when dissipation is removed from or added to some of the Fourier modes.

1096 - Thermo-Acoustic Tomography With Reflectors

Yang Yang, Purdue University

Thermo-Acoustic tomography (TAT) is a recently developed coupled physics imaging modality. In this talk we discuss the mathematical model of TAT with the presence of sound-hard reflectors. We propose an averaged sharp time reversal algorithm which leads to an exponentially convergent Neumann series reconstruction. This is joint work with Plamen Stefanov.

1097 - Localized Anisotropic Regularity Conditions For The Navier-Stokes Equations

Walter Rusin, Oklahoma State University

In this talk, we present a sufficient regularity condition for local solutions of the Navier-Stokes equations. We prove that for a suitable weak solution (u,p) on a domain D, if $\partial_3 u$ belongs to the space $L_t^{s_0} L_x^{r_0}(D)$ where $2/s_0 + 3/r_0 \le 2$ and $9/4 \le r_0\le 5/2$, then the solution is regular.

EIT 318: Highly Accurate and Effective Numerical Methods for Partial Differential Equations

Organizers: Qin Sheng, Abdul Q.M. Khaliq, JaEun Ku
Speakers: JaEun Ku, Songming Hou, Qin Sheng, Wenyuan Liao

1098 - Hybrid Finite Element Methods

JaEun Ku, Oklahoma State University

A new hybrid mixed finite element method will be introduced for efficient and accurate computations of flux variables. The method is a two--step method, based on a system of first-order equations for second-order elliptic partial differential equations. On a coarse mesh, the primary variable is approximated by the standard Galerkin method. Then, on a fine mesh, an $H({\rm div})$ projection is sought as an accurate approximation for the flux variables. The computation on a finer mesh can be carried out very efficiently using well developed preconditioners for the $H({\rm div})$ projection. Also, it will be shown that the mesh size h for the finer mesh can be taken as the square of the coarse mesh size H, or a higher order power with a proper choice of parameter. This means that the computational cost for the coarse-grid solution is negligible compared to that for the fine-grid solution. This is a joint work with Dr. Young Ju Lee and Dr. Dongwoo Sheen.

1099 - Improved Imaging Methods for Extended Targets

Songming Hou, Louisiana Tech University

The MUSIC algorithm is an efficient and robust numerical method for imaging. However, some numerical artifacts are observed around the target(s). We proposed an improved imaging method to generate imaging results better than those from the MUSIC algorithm. We also present some work on the forward solver for domains with multiple corners.

2000 - An Asymptotic Stability of an Eikonal Splitting Method for Solving Paraxial Helmholtz Equations on Arbitrary Transverse Grids

Qin Sheng, Baylor University

This talk concerns the asymptotic stability of an eikonal, or ray, transformation based splitting method for solving the paraxial Helmholtz equation with high wave numbers. Arbitrary grids are considered in transverse directions. The differential equation targeted has been used for modeling propagations of high intensity laser pulses over a long distance without diffractions. Self-focusing of high intensity beams may be balanced with the de-focusing effect of created ionized plasma channel in the situation, and applications of grid adaptations are frequently essential. It is shown that the oscillation-free decomposition method on arbitrary adaptive grids is asymptotically stable with a stability index one. The result can be extended to multidimensional applications. Simulation experiments are given to illustrate our concerns and conclusions.

2001 - An Accurate Numerical Method For Solving 3D Elastic Equation Using Helmholtz Decomposition

Wenyuan Liao, University of Calgary

In an elastic migration or inversion problem, the P and S waves are trated separately, thus efficient numerical solver is required to compute P and S wavefields. Direct solution of an Elastic wave equation is computationally costly, as it is a coupled system of partial differential equations (PDE). Numerical solution of such model is of great interests to both Mathematicians and Geophysicists working on a variety of applications, geophysical exploration for instance. In particular numerical modeling of Elastic wave equation is an integral part of full waveform inversion and other wave equation based seismic inversion methods. Here we propose a new method, in which we first use the Helmholtz decomposition to decouple the Elastic wave equation system into four scalar acoustic wave equations, which are then efficiently solved by compact higher-order finite difference method with high accuracy. Some novel boundary treatments have been developed for the new equations. The numerical solution of the Elastic wave equation is reconstructed from the previously obtained numerical solutions of the four scalar PDEs. Finally numerical examples are solved to demonstrate the efficiency and effectiveness of the newly proposed numerical method.

EIT 319: Operator Splitting Methods For Numerical PDEs And Their Applications

Organizers: Shan Zhao, Qin Sheng
Speakers: Shan Zhao, Alexey Sukhinin, Xinfeng Liu, JaEun Ku, Cheng Wang

2002 - Fast Operator Splitting Algorithms For The Electrostatic Analysis Of Solvated Biomolecules

Shan Zhao, University of Alabama

The Poisson-Boltzmann (PB) equation is an effective model for the electrostatics analysis of solvated biomolecules. The nonlinearity associated with the PB equation is critical when the underlying electrostatic potential is strong, but is extremely difficult to solve numerically. Recently, we have developed an operator splitting framework, in which the nonlinear subsystem is analytically integrated so that the nonlinear instability is completely suppressed. For the linear subsystem, we have explored the electrostatic solution by considering finite difference, finite element, and discontinuous Galerkin methods. Fully implicit alternating direction implicit (ADI) and unconditionally stable locally one-dimensional (LOD) methods have been developed for solving the parabolic equation efficiently. The resulting PB solver scales linearly with respect to the number of atoms, and is promising for studying large macromolecules.

2003 - Spatio-Temporal Modeling of Two-Color Filamentation

Alexey Sukhinin, SMU

In this talk, I will describe the basic mathematical model of the simultaneous co-propagation of high intensity pulses with different wavelengths and different temporal widths. Spatial and temporal effects will be presented based on analysis and numerical simulations. Extension to the two-color filamentation model will be given and discussed.

2004 - Integration Factor Methods For A Class Of High Order Differential Equations

Xinfeng Liu, University of South Carolina

In this talk, we will present an efficient high-order integration factor method for solving a family of high order differential equations, in which the linear high order derivatives are explicitly handled and the computational cost and storage remain the same as to the classic integration factor methods for second-order problems. In particular, the proposed method can deal with not only stiff nonlinear reaction terms but also various types of homogeneous or inhomogeneous boundary conditions. Also such method has recently been extended to solve a hydrodynamic phase field model for a binary fluid mixture of two immiscible viscous fluids.

2005 - An Efficient Solver For A System Of Finite Element Methods For Flux Variable

JaEun Ku, Oklahoma State University

In this talk, a numerical method solving second-order elliptic PDEs is presented. The main goal is obtaining an accurate and efficient approximation for the flux (gradient) variables. A differential equation for the flux variable is obtained from the original equations. The resulting algebraic equation involves solving nearly singular system. An iterative scheme using well-conditioned matrix is presented for the approximation of the solutions for the nearly singular system. This is a joint work with Dr. Lothar Reichel.

2006 - A Second Order Operator Splitting Numerical Scheme For The ``Good" Boussinesq Equation And Its Convergence Analysis

Cheng Wang, University of Massachusetts Dartmouth

The nonlinear stability and convergence analysis is presented for a second order operator splitting scheme applied to the ``good" Boussinesq equation, coupled with the Fourier pseudo-spectral approximation in space. Due to the wave equation nature of the model, we have to rewrite it as a system of two equations, for the original variable and its temporal derivative, respectively. In turn, the second order operator splitting method could be efficiently designed. A careful Taylor expansion indicates the second order truncation error of such a splitting approximation, and a linearized stability analysis for the numerical error function yields the desired convergence estimate in the energy norm. And also, the presented convergence analysis is unconditional for the time step in terms of the spatial grid size, in comparison with a severe restriction time step restriction required in many existing works.

EIT 321: Modeling and Computations for General and Chaotic Biological Systems

Organizers: Majid Bani-Yaghoub, Naveen K. Vaidya, Xianping Li, Noah Rhee

Speakers: Naveen Vaidya, Libin Rong, Songnian Zhao, Maia Martcheva

2007 - Modeling Movements Of HIV In Vaginal Mucus

Naveen Vaidya, University of Missouri - Kansas City

The majority of all female Human Immunodeficiency Virus (HIV) infections are the result of heterosexual intercourse with infected male partners. To establish infection, viruses in semen from HIV-infected partner must penetrate the mucus barrier, which coats and adheres to vaginal epithelia, before they meet underlying CD4+ target cells. In this talk, I will present mathematical models for movements of HIV in vaginal mucus. Using our models, we will study the spatial-temporal distribution of virus in vaginal mucus and time required for the viruses to penetrate mucus layer, and explore how pH level affects these phenomena. Finally, we evaluate the potential nanoparticle-based preventive therapy to control the virus in vaginal mucosa.

2008 - Modeling Viral Control by CD8+ T Cells

Libin Rong, Oakland University

CD8+ T cells play an important role in controlling HIV or SIV (simian immunodeficiency viruses) replication. The most convincing evidence comes from the experiment of CD8+ T cell depletion in SIV-infected nonhuman primates. Despite an obvious temporal relationship between CD8 decrease (increase) and viral load increase (decrease), there are still debates about the underlying explanation for the experimental data. In this talk, I will use a mathematical model to study the dynamics of both T cells and virus during CD8+ T cell depletion and subsequent recovery. The relative contributions to viral control by the target cell availability and specific CD8+ T cell immune responses (direct cell killing vs. non-killing) will be evaluated.

2009 - Optimal Control in Transmission Dynamics of Zoonotic Visceral Leishmaniasis

Songnian Zhao, Department of Industrial and Manufacturing Systems Engineering, Kansas State University

Visceral Leishmaniasis (VL), a vector-borne disease caused by protozoan flagellates of the genus Leishmania, is transmitted by sand flies. After malaria, VL is the second-largest parasitic killer, responsible for an estimated 500,000 infections and 51,000 deaths annually worldwide. Mathematical models proposed for VL have included the impact of dogs versus wild canids in disease dissemination and models developed to assist in control approaches. However, quantitative conditions which are required to control or eradicate VL transmission are not provided and there are not mathematical methods proposed to quantitatively calculate optimal control strategies for VL transmission. The research objective of this work was to model VL disease transmission system (Zoonotic VL in special), perform bifurcation analysis to discuss control conditions, and calculate optimal control strategies.

2010 - Structural And Practical Identifiability Issues Of Immuno-Epidemiological Vector-Host Model

Maia Martcheva, University of Florida

We discuss the structural and practical identifiability of a nested immuno-epidemiological model of arbovirus diseases. We show that the immunological model is not structurally identifiable for the measurements of time-series viremia concentrations. We study a scaled version of the immunological model and prove that it is structurally globally identifiable. After fixing estimated parameter values for the immunological model derived from the scaled model, we develop a numerical method to fit observable Rift Valley Fever epidemiological data to the nested model for the remaining parameter values of the multi-scale system. For the given CDC data set, Monte Carlo simulations indicate that only three parameters of the epidemiological model are practically identifiable when the immune model parameters are fixed. Alternatively, we fit the multi-scale data to the multi-scale model simultaneously. Monte Carlo simulations for the simultaneous fitting suggest that the parameters of the immunological model and the parameters of the immuno-epidemiological model are practically identifiable.

EIT 323: Applied and Computational Topology

Organizers: Henry Adams, Patrick Shipman
Speakers: Francis Motta, Hamza Ghadyali, Chad Giusti, Henry Adams

2011 - A Zoo Of Data And Questions

Francis Motta, Duke University

In this talk I will discuss nascent inquiries into the applicability of TDA methods to datasets derived from complex dynamical systems including measurements and simulations of both Earth's atmosphere and solid surfaces as they are eroded by broad ion beams.

2012 - Topological Patterns in Climatic Data

Hamza Ghadyali, Duke University

Analyzing the rich dynamic structure of climatic data, we find novel patterns using TDA methods. We use persistent homology to explore the geometry of high-dimensional sliding-window curves derived from time-series. We will discuss a novel sliding-window construction, similar to time-delay embeddings, which reveal some structures that are expected and some that are unexpected. For example, we can detect annual periodicity, but we also find oscillations which have connections to other climatic dynamics. These insights may help us to not only further understand climatic patterns, but also to predict climatic quantities of interest.

2013 - Topological Methods In Neuroscience

Chad Giusti, University of Pennsylvania

Modern neuroscience can in large part be characterized by the explosion of new techniques for gathering data from neural systems. Unfortunately, the development of methods for analysis of that data and for understanding the underlying complex systems has not kept pace, creating a strong demand for new quantitative tools which can address the unique challenges present in this domain. We argue that tools from algebraic topology seem, surreptitiously, ideally suited to address these needs and in this talk describe a collection of recent applications in both human and animal neuroscience.

2014 - The Theory Of Vietoris-Rips Complexes: What Is Known And What Is Open?

Henry Adams, Colorado State University

Given a metric space X and a scale parameter $r > 0$, the Vietoris-Rips simplicial complex has as its simplices the finite subsets of X of diameter less than r. These complexes have been applied to problems in computational topology and topological data analysis, but what is known about their theoretical properties? When scale parameter r is small, results by Jean-Claude Hausmann and Janko Latschev show that Vietoris-Rips complexes are well-behaved. However, very little is known about Vietoris-Rips complexes at larger scales. We will discuss Vietoris-Rips complexes of circles, ellipses, and spheres, argue that infinite Vietoris-Rips complexes should be equipped with a different topology (which is a thickening of the metric on X), and survey open questions about larger scale parameters. Joint work with Michal Adamaszek, Florian Frick, and Samadwara Reddy.

EIT 325: Interactions Among Analysis, Optimization and Network Science

Organizers: Pietro Poggi-Corradini, Nathan Albin
Speakers: Nages Shanmugalingam, Lukas Geyer, Michael Higgins, Caterina Scoglio, Daniela Ferrero

2015 - Uniformly Perfect Cantor Sets And Analysis On Trees

Nageswari Shanmugalingam, University of Cincinnati

In this talk we will present results connecting Newtonian spaces of functions on trees with Besov function spaces on Cantor sets. This is joint work with Anders Bjorn, Jana Bjorn and James T. Gill.

2016 - Conformal Dimension Of Sierpinski Carpets

Lukas Geyer, Montana State University

We will present a numerical scheme to calculate conformal dimension of Sierpinski carpets and related fractals. The main tool is the use of discrete p-modulus on graph approximations, based on a similar algorithm Oded Schramm introduced for the special case p=2. This is joint work with Rob Malo.

2017 - Threshold Partitioning Problems and Applications in Statistics

Michael Higgins, Kansas State University

Many statistical problems benefit from the use of networks. Experimental or observational units comprise the nodes. Edge weights measure the pair-wise dissimilarity between prognostically important covariates. A particularly useful class of network optimization problems are threshold partitioning problems---those that impose a constraint on the minimum number of nodes to be contained within a block. Though these problems are often NP-hard, approximate solutions may be found very efficiently. We examine approximate solutions to these problems and show their usefulness in problems of statistical blocking and matching.

2018 - Network-Centric Partner Notification Strategies to Contain Epidemics

Caterina Scoglio, Kansas State University

In this talk, I will present some recent simulation results on the use of network centrality measures to design new partner notification strategies aiming at containing sexually transmitted infectious diseases. The standard partner notification strategy consists on the notification of the infectious status of an individual to all his partners (neighbors in the sexual network). Through partner notification, sexual partners are informed of the high risk of being infected and take preventive measures. Using the susceptible-alert-infected-susceptible (SAIS) model of Sahneh et al., we show the effectiveness of new partner notification strategies through extensive simulation. In these new strategies, in addition to notifying the partners of an infected individual about the infection state of the individual self, if the individual belongs to a small set of nodes with the highest network centrality, his infection status is notified to a large group of individuals in the network. With this strategy, the infection prevalence can be reduced up to 1/3 when the infection status of only 3% of the total individuals is shared. These results suggest the development of an application for mobile phones to broadcast an anonymous alert message when these central individuals are detected to be infected.

2019 - Lower Bounds For The Power Domination Number Of A Graph

Daniela Ferrero, Texas State University

Electric power companies need to monitor the state of their networks continually in order to prevent power surges and black-outs. One method to accomplish this task is to place Phase Measurement Units (PMUs) at selected network locations. The synchronized readings provided by these PMUs, in conjunction with

Kirchhoff's laws, permit to determine the state of the network at any location. Because of the high cost of a PMU, it is important to minimize their number while maintaining the ability of monitoring the entire system. This problem translates into the power domination problem in graph theory. A standard approach to the power domination problem consist of finding power dominating sets and proving they are best possible. However, proving that a set is an optimal power dominating set is usually hard. In this talk we will present the only known lower bound for the power domination problem, with illustrates the connection between the power domination problem in graph theory and the zero-forcing problem in linear algebra. The results are joint work with several colleagues.

ETAS 229: Recent Developments of High Order Numerical Methods

Organizer: Ying Wang
Speaker order: Mustafa Aggul, Dilek Erkmen, Ming-jun Lai, S. Lakshmivarahan

2020 - High Accuracy Approach To Turbulence Modeling

Mustafa Aggul, Michigan Technological Univeirsity

A method is presented, that combines the defect and deferred correction approaches to approximate solutions of Navier-Stokes equations at high Reynolds number. The method is of high accuracy in both space and time, and it allows for the usage of legacy codes – a frequent requirement in the simulation of turbulent flows in complex geometries. In order to obtain a regularization that is second order accurate in space and time, the method computes a low-order accurate, stable and computationally inexpensive approximation (Backward Euler with artificial viscosity) twice. The two-step method is considered here; the results are readily extendable to the higher order accuracy cases by adding more correction steps. Both the theoretical results and the numerical tests provided demonstrate that the computed solution is stable and second order accurate in space and time.

2021 - Defect-Deferred Correction Method For The Two-Domain Convection-Dominated Convection-Diffusion Problem

Dilek Erkmen, Michigan Technological University

We present a method for solving a fluid-fluid interaction problem (two convection-dominated convection-diffusion problems adjoined by an interface), which is a simplifed version of the atmosphere-ocean coupling problem. The method resolves some of the issues that can be crucial to the fluid-fluid interaction problems: it is a partitioned time stepping method, yet it is of high order accuracy in both space and time (the two-step algorithm considered in this report provides second order accuracy); it allows for the usage of the legacy codes (which is a common requirement when resolving flows in complex geometries), yet it can be applied to the problems with very small viscosity/diffusion coeffcients. This is achieved by combining the defect correction technique for increased spatial accuracy (and for resolving the issue of high convection-to-diffusion ratio) with the deferred correction in time (which allows for the usage of the computationally attractive partitioned scheme, yet the time accuracy is increased beyond the usual result of partitioned methods being only first order accurate) into the defect-deferred correction method (DDC). The results are readily extendable to the higher order accuracy cases by adding more correction steps. Both the theoretical results and the numerical tests provided demonstrate that the computed solution is unconditionally stable and the accuracy in both space and time is improved after the correction step.

2022 - Bivariate Spline Solution of Reaction-Diffusion Equations and Its Application

Ming-Jun Lai, University of Georgia

This is a joint work with G. Slavov, based on his dissertation study. We introduce a discrete weak solution to a reaction-diffusion equation with Allee affect. We use a minimization approach and establish the nonnegativity of the solution.Then we use bivariate splines of degree 5 or more to solve the PDE. An application to malaria study will be explained.

2023 - On The Structure Of Energy Conserving Low-Order Models

S. Lakshmivarahan, University of Oklahoma

Starting with the pioneering work of Lorenz in 1963 great strides have been made in the analysis of complex fluid dynamical system. The basic idea behind this approach is to apply Galerkin-type projection technique to a system of partial differential equations to obtain a system of ordinary differential equations (ODE) describing the time evolution of a set of n Fourier amplitudes. The resulting class of ODE has come to be known as the low-order models, LOM(n). Despite the wide spread popularity of this approach, apparently there is no guide lines for the choice of the order n in LOM(n) that would guarantee conservation of energy in the system. It has been observed that lack conservation often leads to non-physical solution for LOM(n). There has been a number attempts to examine the relation between energy conserving LOM(n) and couple gyrostats. Following this lead the present authors have derived a set of sufficient conditions of LOM(n) to conserve energy and have derived a simple algorithm to show that every LOM satisfying these conditions can be rewritten as a system of coupled gyrostats

ETAS 230: Recent Developments in Discontinuous Galerkin Methods for Partial Differential Equations

Organizer: Mahboub Baccouch
Speakers: Yang Yang, Mahboub Baccouch, Bo Dong, Yulong Xing

2024 - Superconvergence Of Discontinuous Galerkin Methods For Nonlinear Hyperbolic Equations

Yang Yang, Michigan Technological University

In this talk, we will focus on the superconvergence of discontinuous Galerkin methods for nonlinear hyperbolic equations. We will demonstrate (2k+1)th order superconvergence rate for problem with fix wind direction. If the wind direction is not fixed, (k+3/2)th order superconvergence rate will be proved. Numerical experiments will be given to demonstrate the optimality of the rates.

2025 - \emph{A posteriori} error analysis of the discontinuous Galerkin method for two-dimensional linear hyperbolic conservation laws on Cartesian grids.

Mahboub Baccouch, University of Nebraska at Omaha.

In this talk, we provide the first \emph{a posteriori} error analysis of the discontinuous Galerkin (DG) method for solving the two-dimensional linear hyperbolic conservation laws on Cartesian grids. The key ingredients in our error analysis are the recent optimal superconvergence results proved in [W. Cao, C.-W. Shu, Y. Yang, and Z, Zhang, \emph{SIAM J. Numer. Anal.}, 53 (2015), pp. 1651-1671]. We first prove that the DG solution converges in the \$L^2\$-norm to a Radau interpolating polynomial under mesh refinement. The order of convergence is proved to be \$p+2\$, when tensor product polynomials of degree at most \$p\$ are used. Then we show that the actual error can be divided into a significant part and a less significant part. The significant part of the DG error is spanned by two \$(p+1)\$-degree right Radau polynomials in the \$x\$ and \$y\$ directions. The less significant part converges to zero at \$\mathcal{O}(h^{p+2})\$. These results are used to construct simple, efficient and asymptotically exact \emph{a posteriori} error estimates. Superconvergence towards the right Radau interpolating polynomial is used to prove that, for smooth solutions, our \emph{a posteriori} DG error estimates converge at a fixed time to the true spatial errors in the L^2-norm at $\mathcal{O}(h^{p+2})$ rate. Finally, we prove that the global effectivity indices in the L^2-norm converge to unity at $\mathcal{O}(h)$ rate. Our proofs are valid for arbitrary regular Cartesian meshes using tensor product polynomials of degree at most p and for both the periodic and Dirichlet boundary conditions. Several numerical experiments are performed to validate the theoretical results.

2026 - Superconvergent HDG Methods For Third-Order Equations In One-Space Dimension

Bo Dong, University of Massachusetts Dartmouth

We design and analyze hybridizable discontinuous Galerkin methods for third-order equations in one-space dimension. The methods are defined as discrete versions of characterizations of the exact solution in terms of local problems and transmission conditions. They provide approximations to the exact solution u and its derivatives $q:=u_x$ and $p:=u_{xx}$ which are piecewise-polynomials of degree k_u, k_q and k_p, respectively. We prove that these methods have superconvergence properties and numerical results are displayed to validate our error estimates.

2027 - A Posteriori Error Estimates Of Local Discontinuous Galerkin Methods For The Generalized Korteweg-De Vries Equations

Yulong Xing, University of California Riverside

The Korteweg-de Vries (KdV) equation is a nonlinear mathematical model for the unidirectional propagation of waves in a variety of nonlinear, dispersive media. Recently it has attracted increasing attention as test-bed for the competition between nonlinear and dispersive effects leading to a host of analytical issues such global existence and finite time blowup, etc. In this presentation, we construct, analyze, and numerically validate a class of discontinuous Galerkin schemes for the generalized KdV equation. We will provide a posteriori error estimate through the concept of dispersive reconstruction, i.e. a piecewise polynomial function which satisfies the GKdV equation in the strong sense but with a computable forcing term enabling the use of a priori error estimation techniques to obtain computable upper bounds for the error. Both semi-discrete and fully discrete approximations are studied.

ETAS 480: Some Advances In Finite Element Methods

Organizers: Yuchuan Chu, Feng Shi
Speaker order: Feng Shi, Xiaozhe Hu, Ju Ming, Yuchuan Chu, Keyu Gong

2028 - A space-time discretization method for solving flow problems based on the partition of unity and adaptivity strategy

Feng Shi, Department of Mathematics, University of Houston

In this talk, we present a fully discrete (space-time) method for solving the flow problems. Along the time advancing, the current method firstly computes a global problem by standard finite element method on the prescribed regular coarse grid; then based on the coarse grid, derives the partition of unity and its associated overlapping subdomains; and solve a series of local residual problems on fine grids of the subdomains which are automatically determined by a adaptivity strategy; finally, obtains the globally continuous finite element solution by assembling all the local solutions together using the partition of unity. The new method can capture the moving boundary layers in the interior of the fluid domain, which will be demonstrated by several numerical experiments.

2029- Weak Galerkin Finite Element Method for the Biot's Consolidation Model

Xiaozhe Hu, Tufts University

Poroelasticity models the processes of coupled deformable porous media flow which is essential in many applications. In this talk, we consider the discretizations for the Biot's model using weak Galerkin finite elements and address the issue related to the non-physical oscillations in the pressure approximation for low permeabilities and/or small time steps. We show that weak Galerkin method provides an oscillation-free scheme numerical and study the well-posedness and convergence of the scheme theoretically. This is a joint work with Lin Mu and Xiu Ye.

2030 - Multi-Level Monte Carlo Finite Element Method for A Stochastic Optimal Control Problem

Ju Ming, Beijing Computational Science Research Center

We consider the application of multi-level Monte Carlo (MLMC) finite element method to an elliptic optimal control problem with uncertain coefficients. Sample size formulae at each level of MLMC were derived from an optimization perspective, by minimizing the computational error subject to a given computational cost or minimizing the computational cost subject to a given error tolerance. A gradient-based optimization algorithm using MLMC was proposed and compared to the results obtained by classical Monte Carlo method. The computational results show the effectiveness MLMC for obtaining accurate optimal solutions that are needed to construct statistical moments associated with the quantity of interest (QoI) of the stochastic control problem at low cost.

2031 - A Dynamic Interface Immersed-Finite-Element Particle-In-Cell Method For Modeling Plasma-Wall Interactions

Yuchuan Chu, Missouri University of Science and Technology

The evolution of wall surface is an unavoidable issue in engineering plasma applications. In this article an iterative method for modeling plasma-wall interactions with dynamic interface is proposed and validated. In this method, the plasma dynamics is simulated by an immersed finite element particle-in-cell (IFE-PIC) method, and the evolution of wall surface is modeled by the Huygens wavelet method which is coupled with the iteration of the IFE-PIC method. Numerical experiments, including prototypical engineering applications such as the erosion of Hall thruster channel wall, are presented to demonstrate features of this dynamic interface IFE-PIC method for simulating the dynamic plasma-wall interactions.

2032 - A Modified Weighting Algorithm for Immersed Finite Element Particle-In-Cell (IFE-PIC) Method

Keyu Gong, Harbin Institue of Technology Shenzhen Graduate School

In the plasma simulation community, the Particle-In-Cell (PIC) scheme has been widely used since its noise-reduction capability and moderate computational expense. Immersed finite elements (IFEs) are relatively new and efficient tools to handle interface problems with Cartesian meshes independent of the interface which are required by PIC scheme. Based on immersed finite element (IFE) methods and Particle-In-Cell methods, the recently developed immersed finite element Particle-In-Cell method (IFE-PIC method) provides an outstanding approach to simulate plasma particles with complex interface boundary. However, in current IFE-PIC method, the charge deposit algorithm does not work very well by depositing the particle charge onto mesh nodes located inside the object described by the interface surface. Also, the process of obtaining the electric field on mesh nodes with the potential of those nodes which locate inside the object has the same drawback. This paper is to present a modified weighting algorithm to improve the accuracy of plasma simulation with IFE-PIC method. Numerical examples are provided to demonstrate the accuracy of IFE-PIC method with new modified weighting algorithm.

ETAS 483: Recent Advance on High Order Numerical Methods for Partial Differential Equations

Organizers: Yuan Liu, Yingda Cheng
Speakers: Yang Jiang, Qi Tang, He Yang, Yuan Liu

2033 - A WENO-based Method of Lines Transpose Approach for Vlasov Simulations

Yan Jiang, Michigan State University

A high order implicit Method of Lines Transpose (MOLT) method based on a weighted essentially non-oscillatory (WENO) methodology is developed for one-dimensional linear transport equations and further applied to the Vlasov-Poisson (VP) simulations via dimensional splitting. In the MOLT framework, the time variable is rst discretized by a diagonally implicit strong-stability-preserving Runge-Kutta method, resulting in a boundary value problem (BVP) at the discrete time levels. Then an integral formulation coupled with a high order WENO methodology is employed to solve the BVP. As a result, the proposed scheme is high order accurate in both space and time and free of oscillations even though the solution is discontinuous or has sharp gradients. Moreover, the scheme is able to take larger time step evolution compared with an explicit MOL WENO scheme with the same order of accuracy. The desired positivity-preserving (PP) property of the scheme is further attained by incorporating a newly proposed high order PP limiter. We perform numerical experiments on several benchmarks including linear advection, solid body rotation problem; and on the Landau damping, two-stream instabilities, bump-on-tail, and plasma sheath by solving the VP system. The efficacy and efficiency of the proposed scheme is numerically verified .

2034 - An Added-Mass/Added-Damping Partitioned Algorithm For Rigid Bodies And Incompressible Flows

Qi Tang, Rensselaer Polytechnic Institute

A stable added-mass/added-damping partitioned algorithm is developed for fluid-structure interaction (FSI) problems involving viscous incompressible flow and rigid bodies. The algorithm remains stable, without sub-iterations, even for light rigid-bodies when added-mass and viscous added-damping effects are large. A fully second-order accurate implementation of the scheme is developed based on a fractional-step method for the incompressible Navier-Stokes equations using finite difference methods and overlapping grids to handle the moving geometry.
We will first present two models problems to motivate and evaluate the properties of the AMP scheme. Then we will present simulations of more complicated FSI problems with some interesting geometry.

2035 - Local Discontinuous Galerkin Methods for Khokhlov-Zabolotskaya-Kuznetzov Equation

He Yang, The Ohio State University

Khokhlov-Zabolotskaya-Kuznetzov (KZK) equation is a model that describes the propagation of the ultrasound beams in the thermoviscous fluid. It contains a nonlocal diff raction term, an absorption term and a nonlinear term. Accurate numerical methods to simulate the KZK equation are important to its broad applications in medical ultrasound simulations. In this paper, we propose local discontinuous Galerkin methods to solve the KZK equation. We prove the L2 stability of our scheme and conduct a series of numerical experiments including the focused circular short tone burst excitation and the propagation of unfocused sound beams, which show that our scheme leads to accurate solutions and performs better than the benchmark solutions in the literature.

2036 - A Simple Bound-Preserving Sweeping Technique For Conservative Numerical Approximations

Yuan Liu, Mississippi State University

In this talk, we introduce a simple bound-preserving sweeping procedure for conservative numerical approximations. Conservative schemes are of importance in many applications, yet for high order methods, the numerical solutions do not necessarily satisfy maximum principle. This paper constructs a simple sweeping algorithm to enforce the bound of the solutions. It has a very general framework acting as a postprocessing step accommodating many point-based or cell average-based discretizations. The method is proven to preserve the bounds of the numerical solution while conserving a prescribed quantity designated as a weighted average of values from all points. The technique is demonstrated to work well with a spectral method, high order finite difference and finite volume methods for scalar conservation laws and incompressible flows. Extensive numerical tests in 1D and 2D are provided to verify the accuracy of the sweeping procedure.

Sunday, October 2, 2016

8:30 a.m. - 10:10 a.m.

EIT 219: Mesh Adaption for Numerical Simulations

Organizers: Xianping Li, Weizhang Huang
Speakers: Stefano Micheletti, Cuiyu He, Avary Kolasinski, Junbo Cheng, Fei Zhang

2037 - Anisotropic mesh adaptation for crack propagation in brittle materials

Stefano Micheletti, Politecnico di Milano, Italy

Quasi-static brittle fracture can be modeled by the Francfort-Marigo model. A suitable approximation to this model can be obtained by the Ambrosio-Tortorelli functional, where the crack is identified by a smooth phase-field, instead of a lower-dimensional set, as in the case of the Francfort-Marigo model. The minimization of the new functional can be found by solving elliptic boundary value problems via a finite element method. Crack propagation exhibits two main length scales, one related to the domain size and the other characterizing the fracture thickness. Mesh adaptation, driven by an a-posteriori error estimator, allows one to refine the grid only in a thin neighborhood of the crack path. In previous works, an anisotropic error estimator and a new minimization algorithms are proposed and applied to the classical Ambrosio-Tortorelli approximation. Several numerical tests assess the reliability of the whole adaptation procedure. In this communication, we extend our previous approach to the generalized Ambrosio-Tortorelli model. Moreover, we address the extension including thermal inelastic effects, which can model the genesis and the propagation of cracks in brittle materials. The numerical verification performed on standard benchmarks in the literature confirms the good accuracy guaranteed by anisotropic grids which yield a significant computational saving.

2038 - Improved ZZ A Posterior Error Estimation For Diffusion Problem

Cuiyu He, Purdue University

For diffusion problems with intersecting interface, a reasonably good approximation requires very small mesh size around the intersecting interface points. As a popular alternative, we use AMR to get a optimal locally refined mesh. In order to obtain a robust A Posteriori error estimation in the sense that constants are independent of the jump of diffusion coefficients which could be very large, we introduce the improved ZZ conforming flux recovery for the confirming FEM. The A Posteriori error estimator and indicators are then defined as the energy norm of the difference between the recovered flux and the numerical one. This procedure shares the advantage with ZZ of very cheap cost, on the other hand, it overcomes the inefficiency of ZZ. Numerical results are presented at last.

2039 - A New Functional For Variational Mesh Generation And Adaption Based On Equidistribution And Alignment Conditions

Avary Kolasinski, The University of Kansas

We will introduce a new meshing functional for variational mesh generation with minimal parameters based on the equidistribution and alignment conditions. We will discuss the theoretical properties of this function including coercivity, nonsingularity, and the existence of limiting mesh. We will present a comparative numerical study of this new functional with one well known functional, which is also based on the equidistribution and alignment conditions.

2040 - A Four-Rarefaction Approximate Riemann Solver With Elastic Wave And Von Mises' Yielding Condition For Two-Dimension Elastic-Plastic Flows

Junbo Cheng, Beijing Institute of Computational Mathematics and Applied Physics

For the equations of two-dimensional elastic-plastic flows with the hypo-elastic constitutive model and von-Mises' yielding condition, it is difficult to build an approximate Riemann solver because of non-conservative hypo-elastic constitutive model and von-Mises' yielding condition. Up to now, there is no good approximate Riemann solver for this problem. In this paper, we first analyse the wave structure of the Riemann problem in the normal direction and develop, accordingly, a four-rarefaction Riemann solver with elastic waves (FRRSE). Because of elastic limit and complex EOS, in constructing FRRSE, one need consider four cases and use a iteration method to solve the problem of FRRSE. Moreover, in order to reduce CPU time of iteration, we use two nested small iterations of two variables to replace one iteration of four variables. Based on FRRSE, we propose a 2nd-order cell-centered Lagrangian scheme. The numerical results show that the present scheme achieves the desired 2nd-order accuracy in space and time. Moreover, a number of numerical experiments show that our scheme is stable, essentially non-oscillatory and appears to be convergent. Moreover, for shock waves the present scheme has comparable accuracy to the scheme of Maire and collaborators, while being more accurate in resolving rarefaction waves.

2041 - A Moving Mesh Method For The Numerical Simulation Of Fracture Propagation

Fei Zhang, China University of Petroleum (Beijing)

In this talk, we present a moving mesh method for the numerical simulation of two dimensional fracture propagation in elastic media using the phase field method. A continuous phase field variable is introduced to describe the "unbroken" or "broken" status of the material, which can model fractures without explicitly tracking discontinuous displacement fields. The behavior of the fracture is then determined by a coupled system of partial differential equations. To avoid the requirement of fine meshes throughout the domain, we apply a variational-type moving mesh method that relocates the mesh nodes automatically to capture the fracture propagation. The numerical results for 2D crack propagation under quasi-static loads are presented, and the effectiveness of the moving mesh method together with phase-field model for fracture simulation is demonstrated.

EIT 224: Partial Differential Equations: Analysis, Computation, Modeling, and Applications

Organizers: John Singler, Weiwei Hu
Speakers: Michael Schmidt, Siwei Duo, Hans-Werner van Wyk, Yangwen Zhang

2042 - Novel Lagrangian Methods for Imperfectly Mixed Chemical Reactions

Michael Schmidt, Colorado School of Mines

Most traditional models for simulating chemical reactions are based on the principle of perfect mixing, which seldom occurs in natural settings. For example, Eulerian methods allow for non-homogeneity across grid points but still require perfect mixing within each grid element. In this talk, we present a novel Lagrangian method known as reactive particle tracking (RPT) that is able to simulate transport and reaction dynamics without the well-mixed assumption needed for other methods. One major advantage of RPT is that it allows for the formation of inhomogeneous "islands" of reactant anywhere in the domain, without the necessity of small-scale discretization. For this reason, RPT is able to model the experimentally observed transition of a well-mixed system into one with imperfect mixing and the subsequent slowdown in reaction speed that follows. As well, the RPT model follows the analytic (well-mixed) PDE solution (with slope t^−1) before transitioning to the imperfectly mixed regime (slope t^{−d/4}, in d dimensions). In this direction, we will describe the algorithm and present some preliminary simulation results.

2043 - Numerical Methods For Solving The Fractional Schrodinger Equation

Siwei Duo, Missouri University of Science and Technology

The fractional Schrodinger equation is a non-local partial differential equation which can describe new phenomena that are absent from the standard Schrodinger equation. However, the nonlocality introduces considerable challenges in solving this equation both analytically and numerically. In this talk, we will present several mass and/or energy conservative methods for solving the fractional Schrodinger equation. The accuracy and the dispersion relation of these methods are studied analytically. Also, we numerically study the plane wave and soliton dynamics, the performance of these methods are compared and discussed.

2044 - Spatial Adaptivity For Numerical PDEs In The Presence Of Parametric Uncertainty

Hans-Werner van Wyk, Auburn University

Localized descriptions of random fields, such as Markov random fields, provide a means of coupling their spatial and stochastic variations. In this talk, we leverage this feature to develop an algorithm for achieving spatial adaptivity in the stochastic setting, through the use of localized, statistical a posteriori error estimators. We illustrate our method with numerical examples.

2045 - Group Finite Element Method For 2D And 3D Navier-Stokes And Boussinesq Equations

Yangwen Zhang, Missouri University of Science and Technology

The standard finite element method for the Navier-Stokes and Boussinesq equations can be very time consuming since the large-scale global matrix must be updated at each nonlinear iteration. We show how group finite elements can be used to treat the nonlinear term; this method is based on interpolation and does not require an update to the global matrix at each iteration. We present 2D and 3D numerical experiments demonstrating (1) the group method has the same accuracy as the standard method, and (2) the group method leads to much faster simulation times, especially for 3D simulations.

EIT 318: Methods Of Applied And Numerical Complex Analysis

Organizers: Anna Zemlyanova, Thomas DeLillo
Speakers: Anna Zemlyanova, Yuri Antipov, Aditi Ghosh

2046 - Two-Dimensional Fluid Flows Around Multiple Cylinders In The Presence Of Vortices

Anna Zemlyanova, Kansas State University

The talk is dedicated to a two-dimensional steady irrotational flow of ideal fluid around multiple cylinders with impenetrable walls in the presence of vortices. Fluid flows in the multiply-connected domains are notoriously difficult to study, and currently very few analytic solutions are available. In this talk, I will describe a simple procedure of building a complex potential of such a flow using method of images and Schottky group. Numerical computations will be presented. The convergence of numerical method is very fast for well-separated cylinders. Study of two-dimensional flows with vortex structures presents an important problem of fluid mechanics and has applications to ocean flows with eddies.

2047 - A Crack Induced By A Thin Rigid Inclusion Partly Debonded From The Matrix

Yuri Antipov, Louisiana State University

The interaction of a thin rigid inclusion with a finite crack is studied. The upper side of the inclusion is completely debonded from the matrix, and the crack penetrates into the medium. It is shown that the problem is governed by a certain singular integral equation. Its closed-form solution is found by solving an associated vector Riemann-Hilbert problem with the Chebotarev-Khrapkov matrix coefficient. A feature of the method proposed is that the vector Riemann-Hilbert problem is set on a finite segment, while the original Khrapkov method of matrix factorization is developed for a closed contour. In the case, when the crack and inclusion lengths are the same, the solution is derived from the general case by passing to the limit. It is demonstrated that the limiting case is unstable, and when the crack length is less than that of the inclusion and the crack tips approach the inclusion ends, the crack tends to accelerate in order to penetrate into the matrix.

2048 - A Fast Fourier Recursive Relation Method To Evaluate Singular Integrals In A Complex Plane

Aditi Ghosh, University Of Idaho, Moscow

A FFTRR based sequential algorithm for solving the Poisson or the biharmonic problem in a unit disk in the complex plane needs evaluation of some singular integrals. We present recursive relations in Fourier space together with fast Fourier transform (FFTRR) which lead to a fast and accurate evaluations of the singular integrals. The complexity of this method to evaluate the singular integrals are $\mathcal{O}(\log_2 N)$ per point compared to $\mathcal{O}(N^2)$ per degree of freedom as in the case of direct evaluation using quadrature method.

EIT 319: Nonlinear Analysis

Organizer: Matt Insall
Speakers: Giles Auchmuty, Shibin Dai, Youngjoon Hong, Ning Ju, Matt Insall

2049 - Nonlinear Boundary Value Problems for Harmonic Functions

Giles Auchmuty, University of Houston

This talk will outline results about the existence and representation of H^1-solutions of Laplace's equation subject to nonlinear Robin, or Neumann, boundary conditions of the form $D_v u + bu = g(u)$ on bounded regions $\Omega\in R^N$. Since the space H of H^1-harmonic functions on is a proper closed subspace of $H^1(\Omega)$, it is sufficient to study this problem on this subspace. Some general existence criteria for solvability will be described. An orthonormal basis of H is given by a class of harmonic Steklov eigenfunctions on Ω. This enables the construction of an integral kernel and a boundary integral equation for solutions that enables other conditions for existence to be obtained. Further properties of the solutions are deduced from this formulation.

2050 - Phase-Field Free Energy and Boundary Force for Molecular Solvation

Shibin Dai, New Mexico State University

We discuss a phase-filed variational model for the solvation of charged molecules with implicit solvent. The solvation free-energy functional of all phase fields consists of the surface energy, solute excluded volume and solute-solvent van der Waals dispersion energy, and electrostatic free energy. The last part is defined through the electrostatic potential governed by the Poisson-Boltzmann equation in which the dielectric coefficient is defined through a phase field. We prove Gamma- convergence of the phase field free-energy functional to its sharp-interface limit. We also define the dielectric boundary force for any phase field as the negative first variation of the free-energy functional, and prove the convergence of such force to the corresponding sharp-interface limit.

2051 - Theoretical And Numerical Analysis Of Singularly Perturbed Problems

Youngjoon Hong, University of Illinois, Chicago

In this talk, we consider various singularly perturbed problems. The main focus has been the use of a correction function usually called the "corrector" (proposed by J. L. Lions), which resolves the discrepancy between the zero boundary conditions and those of the outer solutions, in order to analyze boundary layers. Introducing the corrector function, the specific convergence rate is explored in certain spaces. In addition, some new semi-analytic methods have been proposed and successfully applied under the names of enriched spaces. The main ingredient of the enriched method is to add a global basis function, and supplement the discrete space with the corrector functions. In our treatment, we implement the modified finite element method using a quasi-uniform mesh which remains unchanged as time evolves.

2052 - Solution Regularity for the Primitive Equations

Ning Ju, Oklahoma State University

Some new results recently obtained by the speaker about the Primitive Equations for large scale oceanic flows will be presented and discussed.

2053 - Advances in the Mathematical Analysis of the Complete Iterative Inversion Method

Matt Insall, Missouri S&T

We expand on the Complete Iterative Inversion Method (CIIM) used in physical chemistry to generate an energy potential of a gas system. While originally designed to be used with Lennard-Jones potentials, we explore, among other things, the application of the CIIM to step functions which approximate Lennard-Jones potentials. This is joint work with Abdulrahman S. Alharbi, David E. Grow, and Brittany M. Cuchta

EIT 321: Modeling and Computations for General and Chaotic Biological Systems

Organizers: Majid Bani-Yaghoub, Naveen K. Vaidya, Xianping Li, Noah Rhee
Speakers: Majid Bani-Yaghoub, James Moore, Jin Wang, Joe Tien

2054 - Optimal Control Policies For Reducing Johne's Disease In Dairy Farms

Majid Bani-Yaghoub, University of Missouri-Kansas City

Johne's disease is a chronic contagious infection, caused by Mycobaterium paratuberculosis. Each year, the U.S. dairy industry loses over 200 million dollars due to the infection. Using the cattle movement data of six dairy farms and the Johne's disease data, a mathematical model is developed to determine control policies that can minimize the prevalence of infection in a dairy farm. The model incorporates progression of the infection within each pen and the cattle movements between the pens. Using the basic and target reproduction numbers, the infection risk in each pen is calculated. It is shown that the overall infection risk is substantially reduced when the average residence time and the population size in high risk pens are minimized. Using numerical simulations, spread of epidemic waves in dairy farms and impacts of control measures are numerically explored. This is a joint work with Malinee Konboon.

2055 - Modeling the Acceleration and Delay of Type 1 Diabetes by Viral Infection

James Moore, Emory University

It has been suggested that lack of childhood infection may predispose individuals to autoimmune diseases such as type 1 diabetes. Experimental infections of laboratory mice suggest that the age of exposure to certain viral infections is a key determinant of diabetes susceptibility. Mice infected at an earlier age tend to be protected while mice infected at a later age become more prone to diabetes. Biologists have suggested several hypotheses to explain this pattern such as immune regulation, immune competition and infection induced inflammation. In this talk, I will present a mathematical model of type 1 diabetes and viral infection and use it to evaluate the plausibility of each hypothesis.

2056 - Modeling Cholera In Heterogeneous Environments

Jin Wang, University of Tennessee at Chattanooga

We present some recent work in mathematical modeling of cholera, a severe water-borne infectious disease. Particularly, we discuss the impacts of spatial heterogeneity and seasonal variation on the transmission dynamics of cholera, using both mathematical analysis and numerical simulation. Based on a deterministic modeling framework that involves systems of ODEs and PDEs, we establish results of disease extinction and persistence for each model, and compare the threshold dynamics in homogeneous and heterogeneous settings.

2057 - Modeling The Trade-Off Between Transmission And Contact In Disease Dynamics

Joe Tien, The Ohio State University

Symptom severity affects disease transmission both by impacting contact rates, as well as by influencing the probability of transmission given contact. This involves a trade-off between these two factors, as increased symptom severity will tend to decrease contact rates, but increase the probability of transmission given contact (as pathogen shedding rates increase with symptom severity). Here we explore this trade-off between contact and transmission given contact, using a simple compartmental susceptible-infected-recovered type model. Under mild assumptions on how contact and transmission probability vary with symptom severity, we give sufficient, biologically intuitive criteria for when the basic reproduction number varies non-monotonically with symptom severity. Multiple critical points are possible. We give a complete characterization of the region in parameter space where multiple critical points are located in the special case where contact decreases exponentially with symptom severity. We consider a multi-strain version of the model with complete cross-immunity and no super-infection. In this model, we prove that the strain with highest basic reproduction number drives the other strains to extinction. This has both evolutionary and epidemiological implications, including the possibility of an intervention paradoxically resulting in increased disease prevalence. This is joint work with Chiu-Ju Lin and Kristen Deger.

EIT 323: Applied and Computational Topology

Organizers: Henry Adams, Patrick Shipman
Speakers: Rachel Neville, Patrick Shipman, Pawel Dlotko, David Letscher

2058 - Topological Measure of Order on Lattice Patterns

Rachel Neville, Colorado State University

Pattern-forming systems can give rise to perfect or near-perfect lattice patterns. For instance, bombarding a binary surface with a broad ion beam can lead to hexagonal arrays of nanodots. It is necessary to be able to measure the degree of order present in a pattern to identify not only variation in the pattern, but also defects. With D. Pearson, M. Bradley, F. Motta, and P. Shipman, we purpose a topological method relying on persistent homology to measure the degree of order present in a pattern. There are several standard methods of measuring order using Fourier methods, the autocorrelation function, and a nearest-neighbor measure. We will compare these methods with our topological method for various lattice patterns.

2059 - The Soft Mode Plays A Role In Defect Persistence In Pattern-Forming Systems

Patrick Shipman, Colorado State University

When the surface of a nominally flat binary material is bombarded with a broad, normally incident ion beam, disordered hexagonal arrays of nanodots can form. Defects, such as dislocations in ripple patterns or penta-hepta pairs in hexagonal arrays, limit the utility of patterns produced by ion bombardment. We show that a neutrally stable soft mode can contribute to the persistence over time of defects that form in the early stages of pattern formation. Topological measures of order provide a method for determining if a defect is removed as the pattern evolves.

2060 - Computational topology and computational electromagnetism

Pawel Dlotko, Inria Saclay

It is not well recognized in the topology and physics community that from the very early years of their existence unified theory of electricity and magnetism and algebraic topology are closely related. Concepts which have clear physical interpretation are well defined objects in homology and cohomology theory. Recent advantages in computational topology makes this relation even more interesting since now we have efficient algorithms and their implementations at our disposal, and we can use them in computational electromagnetism.
During this presentation we will describe my long and ongoing cooperation with Ruben Specogna on the problems between computational electromagnetism and algebraic topology. We will focus on the eddy current approximation to Maxwell's equations. We will show how one can build discrete counterparts of Maxwell's equations on a finite polyhedral mesh, and how concepts from homology and cohomology are essential to make the whole theory work. Later we will summarize our quest for efficient and easy to use algorithm to compute topological invariant needed to solve Maxwell's equations. We will show how the two theories can benefit from each

other in a matter of knowledge and efficient computational methods. In particular, we will present an topology based idea we discovered which is currently used in commercial solvers of Maxwell's equations.

2061 - Persistent Homotopy: An Overview

Davi Letscher, Saint Louis University

We provide a overview of the use of homotopy groups to study topological persistence. In particular, we will focus on 3-dimensions where we can utilize normal surface theory to construct theoretical algorithms. These algorithms can be used to calculate persistent homotopy groups, construct persistence diagrams and perform topological simplification.

EIT 325: Interactions Among Analysis, Optimization And Network Science

(8:05 a.m. - 10:10 a.m.)

Organizers: Pietro Poggi-Corradini, Nathan Albin
Speakers: Jason Clemens, Jim Gill, Thiwanka Fernando, Hrant Hakobyan

2062 - Blocker Duality for Modulus

Jason Clemens, Missouri Valley College

Using the formulation given by Fulkerson, we explore the idea of blocking duality as it pertains to the modulus of families of objects on finite undirected graphs. In particular, we generalize the concept of conjugate family in complex analysis and obtain a relation between the p-modulus of family of objects and a related p'-modulus for its blocker family. As an example, we discuss the family of all spanning trees and show that the Fulkerson blocker is different from the combinatorial blocker (the family of all cuts) in this case.

2063 - Modulus and Spaces Without Walks

James Gill, Saint Louis University.

We discuss spaces without enough paths to make modulus an available tool. What can still be said?

2064 - An Investigation Of Node-Based Metrics On Networks Arising From P-Modulus

Thiwanka Fernando, Kansas State University

p-Modulus of families of walks on graphs generalizes and interpolates among three important quantities in graph theory: shortest path, effective resistance and max-flow/min-cut. Let τ(a,b) be the family of walks originating at a and terminating at b.We have shown that the reciprocal of min cut, Mod_1(τ(a,b))^{-1} is also a metric and more generally, d_p(a,b):= Mod_p(τ(a,b))^{-1/p} is a metric for all 1≤ p < ∞. When p tends to infinity d_p recovers shortest-path, but when p=2, d_p is the square-root of effective resistance and effective resistance itself is a metric. Therefore, it is natural to ask what is the optimal function τ(d_p) that yields a metric for each p. We wish to investigate the optimal exponent τ(p):=sup{t: d_p^t is a metric}. We produced sets of 50 Erdτs-Renyi graphs on 10 nodes with average degree 6 and found that τ(p)=p works for 1≤ p ≤2. For p>2, τ(p) seems to be a decreasing function that converges to 1. We also found examples for p>2 where d_p^p = Modp(τ(a,b))^{-1} is not a metric. However, we conjecture that Modp(τ(a,b))^{-1} serves as a metric for 1≤ p ≤ 2 and so far this is confirmed numerically.

2065 - Quasisymmetric Embeddings Of Metric Spaces

Hrant Hakobyan, Kansas State University

A mapping between metric spaces is called quasisymmetric if it distorts relative distances and sizes of sets by a bounded amount. One of the most important questions in the theory is the problem of quasisymmetrically embedding a metric space into a Euclidean space. In this talk we will define a class of spaces called slit carpets and will completely characterize those slit carpets which can be embedded quasisymetrically into the plane. The main tools are classical and transboundary modulus of families of curves.

2065A - A Hamilton Type Gradient Estimate For Solutions To The Heat Equation On Graphs

Paul Horn, University of Denver

In this talk we will describe how to derive a gradient estimate for positive solutions to the heat equation on graphs satisfying a curvature lower bound. The gradient estimate derived, unlike the classical Li-Yau inequality, controls how the solution changes in space alone and is originally due to Hamilton in the manifold case. Our curvature type is a variant of the curvature dimension inequalities $CD (n, K)$ of Bakry and Emery, known as $CDE(n, K)$, which was introduced in work of the speaker and others in deriving a version of the Li-Yau inequality for graphs. One nice feature of the estimate is that, unlike the Li-Yau inequality, it is dimension independent and applies to some graphs which are known to satisfy $CDE(\infty, 0)$ but do not satisfy $CDE(n, 0) for any finite n. Some applications will be briefly discussed as well.

ETAS 229: Recent Developments of High Order Numerical Methods

Organizer: Ying Wang
Speaker order: Songting Luo, Lin Mu, Jin-song Pei, Ran Zhang

2066 - High-Order Methods For Traveltime And Amplitude In Fast Huygens Sweeping Method For High Frequency Helmholtz Equation

Songting Luo, Iowa State University

We present efficient methods to compute high order accurate traveltime and amplitude. Efficient factorization approaches are presented to resolve the source singularities such that high-order methods can be designed and applied effectively to obtain high-order accurate traveltimes and amplitudes. With high accurate traveltimes and amplitudes, we present an efficient method, namely the fast Huygens sweeping method, to solve the Helmholtz equation in the high frequency regime. Numerical examples verify the effectiveness of the methods.

2067 - Weak Galerkin Finite Element Methods and Implementations

Lin Mu, Oak Ridge National Laboratory

The Weak Galerkin method is a new discontinuous version of finite element methods for solving partial differential equations. The key is to replace the classical derivatives weakly defined derivatives on functions with discontinuity. The WG methods have the flexibility in handling complex geometry and low regularity solutions, the simplicity in formulation. In this talk, we will talk about the numerical formulations and implementations of the weak Galerkin framework.

2068 - A Brief Introduction to "Mem-Models" in Engineering Mechanics Applications

Jin-Song Pei, The University of Oklahoma

A significant event happened for electrical engineering in 2008, when researchers at HP Labs announced that they had found "the missing memristor", a fourth basic circuit element that was postulated nearly four decades earlier by Dr. Leon Chua who also developed the theory of memristive systems. One consequence of this announcement has been revitalized research in all areas of brain-imitating computer technologies, primarily because memristors mimic synapses. Moreover, the theory involving memristor devices and memristive systems was extended to include memcapacitors and meminductors, thereby introducing an entire class of "mem-models". This model class is the foundation of the present study. By applying well-known mechanical-electrical system analogies, the mathematics of mem-models may be transferred to the setting of engineering mechanics, resulting in mechanical counterparts of memristors, memcapacitors, etc. We identify some recent examples of "mem-dashpots" and "mem-springs". In addition to a "zero-crossing" condition, we highlight the role played by discontinuities in the model and/or the excitation, the combination of which enables mem-models to produce numerous hysteresis patterns. We also consider some new properties and modeling techniques that call for further improvement so that these new types of mechanical models can become more usable for analyzing real-world data.

2069 - Maximum Principles For P1-P0 Weak Galerkin Finite Element Approximations Of Quasi-Linear Second Order Elliptic Equations

Ran Zhang, Jilin University

This talk will introduce maximum principles for the weak Galerkin method dealing with the second order elliptic equation. Under the h-acute assumption for the mesh partition, two maximum principles with respect to midpoints are proved. The theoretical analysis is based on the variational form and De Giorgi technique. Some numerical results are also presented.

ETAS 230: Recent Developments in Discontinuous Galerkin Methods for Partial Differential Equations

Organizer: Mahboub Baccouch
Speakers: Joshua Buli, Ari Stern, James Rossmanith, Bahaudin Hashmi

2070 - A Local Discontinuous Galerkin Method for the Coupled BBM-BBM System

Joshua Buli, University of California, Riverside

The well known Euler equations for fluid flow can be approximated using the four-parameter class of equations known as the "abcd" Boussinesq equations. With a specific choice of these parameters, one obtains the coupled BBM-BBM system which approximates the 2D propagation of surface waves in a channel. We present a local discontinuous Galerkin method to solve the coupled BBM-BBM system. The high order Runge-Kutta methods, and midpoint rule are utilized for the time discretization. Numerical examples are shown to establish accuracy and stability of the method, including generation of soliton waves and head on collisions of solitary waves.

2071 - Multisymplectic HDG methods

Ari Stern, Washington University in St. Louis

For Hamiltonian ODEs, symplectic numerical methods exhibit superior numerical performance. For Hamiltonian PDEs, a suitable numerical method should be "multisymplectic" -- but what does this mean? We answer this question using the "unified framework" of Cockburn et al. for hybridizable discontinuous Galerkin (HDG) methods, which turns out to be particularly well-suited to this problem. Specifically, we give necessary and sufficient conditions for an HDG method to be multisymplectic, and examine these criteria for several popular methods.
(Joint work with Robert McLachlan, Massey University, New Zealand.)

2072 - High-order DG-FEM for Micro-Macro Partitioned Kinetic Models

James Rossmanith, Iowa State University

The dynamics of gases can be simulated using kinetic or fluid models. Kinetic models are valid over most of the spatial and temporal scales that are of physical relevance in many application problems; however, they are computationally expensive due to the high dimensionality of phase space. Fluid models have a more limited range of validity, but are generally computationally more tractable than kinetic models. One critical aspect of fluid models is the question of what assumptions to make in order to close the fluid model. In this work we develop a high-order discontinuous Galerkin finite element method (DG-FEM) for a so-called micro-macro decomposition approximation of the kinetic equations. The micro-macro decomposition approach allows us to obtain accurate solutions of the fluid model, but instead of forcing a particular moment-closure approximation, which would typically only have a limited range of validity, this approach directly solves a version of the kinetic equations and uses this solution to provide a closure for the fluid equations. The proposed approach in this work makes use of an efficient semi-Lagrangian DG method for solving the kinetic portion of the update. The resulting numerical method is validated on several standard test cases.

2073 - Modeling of Important Vapor-to-Particle Reactions

Bahaudin Hashmi, Colorado State University

In this talk we discuss the threshold kinetics that govern the formation of Liesegang rings in the ammonia and hydrogen chloride reaction. Liesegang ring formation is a special type of chemical pattern in which a spatial order is formed by density fluctuations of a weakly soluble salt. For this reaction diffusion system we use a Continuous Galerkin finite element scheme to analyse the system in both one dimension and two dimensions. With our simulations we try to match amplitude and frequency data of the reaction from experiments.

ETAS 480: Some Advances in Finite Element Methods

Organizers: Yuchuan Chu, Feng Shi
Speaker order: Fatma Songul Ozesenli Tetikoglu, Lulu Quan, Fatih Sabahattin Tetikoglu, Yingwei Wang

2074 - Numerical Solution of an Elliptic-Hyperbolic Equation with an Unknown Parameter

Fatma Songul Ozesenli Tetikoglu, Fatih University

In the present study, the boundary value problem for the elliptic-hyperbolic differential equation with an unknown parameter in a Hilbert space with self adjoint definite operator is investigated. The well-posedness of this problem is established. The stability inequalities for the solution of source identification problem for elliptic-hyperbolic equations are obtained. The first and second order of accuracy difference schemes approximately solving the boundary value problem are presented. The stability estimates for the solutions of these difference schemes are established.

2075 - Time-domain Immersed Finite Element Methods for Electromagnetic Scattering and Radiation in Composite Material

Lulu Quan, Harbin Institue of Technology Shenzhen Graduate School

This paper solves the wave equation interface problem with immersed finite element (IFE) method. This problem arises from electromagnetic scattering and radiation simulation in composite materials. The meshes used in these IFE methods can be independent of the interface geometry and position; therefore, if desired, a structured mesh such as a Cartesian mesh can be used in an IFE method to simulate 2-D scattering and radiation in a domain with non-trivial interfaces separating different materials. Numerical examples are provided to demonstrate that the accuracies of these IFE methods are comparable to the standard finite element method with unstructured body-fit mesh.

2076 - The positivity of the difference operator with periodic conditions and its application
Fatih Sabahattin Tetikoglu, Fatih University

In this study, the second order of approximation of the difference operator is presented. The positivity of this operator in a Banach space is established. In application, theorems on well-posedness for difference schemes of the approximate solution of the boundary value problem for elliptic differential equations are presented.

2077 - Muntz-Galerkin Methods And Applications To Mixed Dirichlet-Neumann Boundary Value Problems
Yingwei Wang, Purdue University

Solutions for many problems of interest exhibit singular behaviors at domain corners or points where boundary condition changes type, which adversely a ects the accuracy and convergence of standard numerical methods. We developed a Muntz-Galerkin method which is based on specially tuned Muntz polynomials to deal with the singular behaviors of the underlying problems. By exploring the relations between Jacobi polynomials and Muntz polynomials, we developed efficient implementation procedures for the Muntz-Galerkin method and provide optimal error estimates. As examples of applications, we considered the Poisson equation with mixed Dirichlet-Neumann boundary conditions, whose solution behaves like $O(r^{1/2})$ near the singular point, and demonstrate that the Muntz-Galerkin method greatly improves the rates of convergence of the usual spectral method.

ETAS 483: Contributed presentations
Speakers: Adelaide Akers, Dennis Brewer, Rong Fan, S. Lakshmivarahan, Hung Le

2078 - Existence and Symmetry of Small-amplitude Solitary Water Waves with Discontinuous Vorticity
Adelaide Akers, University of Missouri-Columbia

We consider the classical water wave problem comprised of a two-dimensional body of water with constant density which lies below a vacuum. The ocean bed is assumed to be impenetrable, while the boundary which separates the fluid and the vacuum is assumed to be a free boundary. Following the work of M.D. Groves and E. Wahlen (2008), we use the Hamiltonian structure of the system coupled with center manifold reduction techniques to establish the existence of small-amplitude solitary water waves with discontinuous vorticity. Furthermore, we utilize a modified moving planes method to show that such solitary waves possess even symmetry.

2079 - An Introductory Course in Partial Differential Equations Using Mathematica
Dennis Brewer, University of Arkansas, Fayetteville

An upper-level undergraduate course in partial differential equations is offered each semester at the University of Arkansas. The course stresses applications and analytic methods for solving the heat equation, wave equation, and Laplace equation with particular emphasis on series solutions of orthogonal functions. This talks discusses a supplementary text written in the form of a Mathematica notebook. This interactive format allows students to explore larger classes of orthogonal functions and consider the nature of the convergence of series solutions, including Gibbs Phenomenon. Animations in Mathematica also facilitate dynamic visualization of time-dependent solutions of partial differential equations in one or two space variables.

2080 - A Squared Correlation Coefficient of the Correlation Matrix
Rong Fan, Southern Illinois University

Multivariate linear correlation analysis is important in statistical analysis and applications. This paper defines a one number summary gamma^2 of the population correlation matrix that behaves like a squared correlation. The squared Pearson's correlation coefficient is a special case of gamma^2 for two variables. Unlike the coefficient of multiple determination, also known as the multiple correlation coefficient, gamma^2 does not depend on the choice of the dependent variable.

2081 - Data Ming, Data Assimilation and Prediction - Parts of a Continuum
S. Lakshmivarahan, University of Oklahoma

Data mining relates to the process of solving a class of inverse problems - of building the models from data much like Kepler discovered his famous four laws from the analysis of the astronomical observations and the way we build models for times series today. Models come in various shapes and forms- (a) static/dynamic (b) deterministic/stochastic and (c) causality based or empirical. Independent of its type, models have unknown parameters and/or initial conditions. These unknowns are estimated using the very same data that lead to the model in the first place. Recall that Gauss fitted a model for the for the path of Ceres, using the past observations and then estimated the parameters of the model using the method of least squares that he invented for this purpose. This aspect of estimating the parameters of the model has come to be known as data assimilation. Using the assimilated model we then generate the forecast much like Gauss was able to predict the time and bearings for the reappearance of Ceres.

2082 - The Transmission Problem for Elliptic Equations with Wentzel Boundary Condition
Hung Le, University of Missouri-Columbia

The talk presents some results about the existence and uniqueness of weak and classical solutions for elliptic equations with transmission problem and Wentzel boundary condition. Applications to steady water waves in the presence of wind will be discussed.

Sunday, October 2, 2016
10:40 a.m. - 12:20 p.m.

EIT 219: No scheduled talks

EIT 224: No scheduled talks

EIT 318: Methods Of Applied And Numerical Complex Analysis
Organizers: Anna Zemlyanova, Thomas DeLillo
Speakers: Tom DeLillo, Justin Mears, Mehran Mehrabi

2083 - A Comparison of Some Numerical Conformal Mapping Methods for Simply and Multiply Connected Domains
Thomas DeLillo, Wichita State University

We compare some methods for computing conformal maps from simply and multiply connected domains bounded by circles to target domains bounded by smooth curves and curves with corners. We discuss the use of explicit preliminary maps, including the osculation method of Grassmann, to first conformally map the target domain to a more nearly circular domain. The Fourier series method due to Fornberg and its generalizations to multiply connected domains are then applied to compute the maps to the nearly circular domains. The final map is represented as a composition of the Fourier/Laurent series with the inverted explicit preliminary maps. A novel method for systematically removing corners with power maps is also implemented and composed with the Fornberg maps (which require smooth boundaries) and the level of error that can be expected when using Fourier series to treat domains with corners is illustrated. This is joint work with Mohamed Badreddine.

2084 - Computation of Stokes Waves Using Conformal Mapping

Justin Mears, Wichita State University

Stokes waves for water of infinite and finite depth are computed using numerical methods for conformal mapping of simply and doubly connected domains, resp. These two dimensional, time dependent waves satisfy dynamic and kinematic conditions on the free surface of the fluid. The periodic waves at each time step are mapped to bounded domains and modifications of Fornberg's method for simply and doubly connect domains are used to map the unit disk or an annulus to the simply and doubly connected domains. The transplanted boundary value problems for the velocity potential are solved by Fourier series in the disk or annulus and the velocity potential and free surface are advanced in time. This is joint work with Thomas DeLillo.

2085 - Analytical Analysis of Gas Diffusion into Noncircular Pores of Shale Organic Matter

Mehran Mehrabi, The University of Texas at Austin

Total gas in shale gas reservoirs sourced from free, adsorbed and dissolved/diffused gas. The mechanisms of production of free and adsorbed gas have been studied by numerous researchers. In contrast, evolution of the dissolved gas and its contribution to the total gas production is not well understood. In this study we model the effect of pore microstructure in organic matter (OM) on the rate of gas production in shale reservoirs. In this regard, first, we solve the gas-in-solid diffusion equation over a general doubly-connected spatial domain with an external Neumann and internal Dirichlet boundary conditions. The obtained solution is applied systematically to multi-pore porous OM domains and then, the effect of pore morphology on the rate of gas production is studied. Our model results show that pore geometry has slight effect on gas diffusion process, while total organic content (TOC), and OM porosity, pore size distribution, and specific surface area are dominant parameters. Abundance of very small pores in OM tremendously increase diffuse gas contribution in total gas reserve and production.

EIT 319: Contributed talks

Speakers: Lasanthi Pelawa Watagoda, Liangya Pi, Changxin Qiu, Hasthika Rupasinghe Arachchige Don

2086 - Inference After Variable Selection

Lasanthi Pelawa Watagoda, Southern Illinois University; Dr. David Olive

This work presents inference for the multiple linear regression model Y = beta_1x_1 + ... + beta_px_p + e after variable selection, including prediction intervals for a future value of the response variable Y_f given a p x 1 vector of predictors x_f , and testing hypotheses with the bootstrap. If n is the sample size, most results are for n >> p, but prediction intervals are developed that increase in average length slowly as p increases for fixed n, if the model is sparse: k predictors have nonzero coefficients beta_i where n >> k

2087 - An Investigation on the Data Assimilation with Kalman Filter and Finite Elements for Subsurface Flows

Liangya Pi, Missouri University of Science and Technology

Kalman filter has been showed to be a very efficient tool for data assimilation. Based on the state equation and observation equation arising from the finite element discretization in space, we utilize the Kalman filter to investigate the effect of the data noise, low solution regularity, and the number and locations of observation wells for subsurface flow problems.

2088 - A Multi-Physics Domain Decomposition Method for Navier-Stokes-Darcy Model

Changxin Qiu, Missouri University of Science and Technology

In a karst aquifer, free flow and porous media flow are tightly coupled together, for which the Navier-Stokes-Darcy model has higher fidelity than either the Darcy or Navier-Stokes systems on their own. The Stokes-Darcy type model has attracted significant attention in the past ten years. However, coupling the two constituent models leads to a very complex system. This presentation discusses a multi-physics domain decomposition method for solving the Navier-Stokes-Darcy system. Computational results are presented to illustrate the features of the proposed method and the convergence analysis is demonstrated.

2089 - Bootstrapping Analogs of the Two Sample Hotelling's T^2 Test}

Hasthika Rupasinghe Arachchige Don, Southern Illinois University; Lasanthi Pelawa Watagoda

Suppose there are two independent random samples from two populations or groups. A common multivariate two sample test of hypotheses is H_0: mu_1 = mu_2 versus H_1: mu_1 not equal to mu_2 where mu_i is a population location measure of the ith population for i = 1, 2. The two sample Hotelling's T^2 test is the classical method, and is a special case of the one way MANOVA model if the two populations are assumed to have the same population covariance matrix. This paper suggests using the Olive (2016ab) bootstrap technique to develop analogs of Hotelling's T^2 test. The new tests can have considerable outlier resistance, and the tests do not need the population covariance matrices to be equal.

EIT 321: Modeling and Computations for General and Chaotic Biological Systems

Organizers: Majid Bani-Yaghoub, Naveen K. Vaidya, Xianping Li, Noah Rhee

Speakers: Xianping Li, Weijiu Liu, Gayla Olbricht, Yi Sun

2090 - Mathematical Modeling and Computation of Spatio-temporal Dynamics of Dengue Epidemics

Xianping Li, University of Missouri-Kansas City

In recent years, growing spatial spread of dengue, a mosquito-borne disease, has been a major international public health concern. Many epidemiological parameters, including those related to mosquito entomology, highly depend on temperature, indicating that the spatial variation of temperature may have important effects on the spatial spread of dengue. In this talk, we will present a mathematical model to describe spatio-temporal transmission dynamics of dengue. Using our model, we evaluate how variation of temperature across space can affect the spatial expansion of dengue epidemics. Our results may provide useful information for effective deployment of spatially targeted interventions.

2091 - Asymptotic Tracking and Disturbance Rejection of the Blood Glucose Regulation System

Weijiu Liu, University of Central Arkansas

Type 1 diabetes patients need external insulin to maintain blood glucose within a narrow range from 65 to 108 mg/dl (3.6 to 6.0 mmol/L). A mathematical model for the blood glucose regulation is required for integrating a glucose monitoring system into insulin pump technology to form a closed-loop insulin delivery system on the feedback of the blood glucose level, the so-called "artificial pancreas." We present such a model by treating the exogenous glucose from food as a glucose disturbance and developing a closed-loop feedback and feedforward control system. We show that the glucose disturbance can be generated by an exogenous periodic system and the center manifold theory can be used to establish blood glucose regulator equations, and then the required feedback and feedforward controllers to reject the disturbance and asymptotically track the glucose reference can be synthesized by.using the solutions of the regulator equations.

2092 - Modeling Sleep Patterns In The Fruit Fly To Investigate The Link Between Sleep And Alzheimer's Disease

Gayla Olbricht, Missouri University of Science and Technology

Sleep is a critical, restorative process that is imperative to human health, yet links between sleep and many health outcomes are not well understood. Sleep is often disrupted in patients with Alzheimer's Disease (AD) and the brains of sleep deprived people may not clear aggregating proteins appropriately, potentially leading to AD. We utilize the fruit fly, Drosophila melanogaster, as a model system to better understand how an individual's sleep pattern may predict the susceptibility or severity of disease progression. Using genetic techniques, different degrees of disease severity of an Alzheimer's like condition can be induced in the fly. The sleep-wake status of individual flies is monitored over the fly lifespan and used to create descriptive variables, such as transition probabilities of staying asleep or awake from one minute to the next (a measure of sleep or wake consolidation). When calculated on a daily basis, it is informative to study how these variables change over time. We employ methods based on first differences and functional principal component analysis to summarize trajectories over time. Through this work, we examine sleep patterns differences between flies with and without Alzheimer's and use sleep variables as predictors of longevity and an individual's potential AD susceptibility.

2093 - Kinetic Monte Carlo Simulations of Multicellular Aggregate Self-Assembly in Biofabrication

Yi Sun, University of South Carolina

We present a three-dimensional lattice model to study self-assembly and fusion of multicellular aggregate systems by using kinetic Monte Carlo (KMC) simulations. This model is developed to describe and predict the time evolution of postprinting morphological structure formation during tissue or organ maturation in a novel biofabrication process (or technology) known as bioprinting. In this new technology, live multicellular aggregates as bio-ink are used to make tissue or organ constructs via the layer-by-layer deposition technique in biocompatible hydrogels; the printed bio-constructs embedded in the hydrogels are then placed in bioreactors to undergo the self-assembly process to form the desired functional tissue or organ products. Here we implement our model with an efficient KMC algorithm to simulate the making of a set of tissues/organs in several designer's geometries like a ring, a sheet and a tube, which can involve a large number of cells and various other support materials like agarose constructs etc. We also study the process of cell sorting/ migration within the cellular aggregates formed by multiple types of cells with different adhesivities.

EIT 323: Applied and Computational Topology

Organizers: Henry Adams, Patrick Shipman
Speakers: Amit Patel, Lori Ziegelmeier, Isabel Darcy, Iuliana Oprea

2094 - Semicontinuity of Persistence Diagrams

Amit Patel, Colorado State University

The persistence diagram is very different in philosophy from the barcode. Suppose we have a constructible persistence module of vector spaces. Its barcode is its list of indecomposables. Its persistence diagram is an encoding of all persistent vector spaces. In the setting of vector spaces, we know that these two notions are equivalent. However, we quickly run into problems if we try to generalize the barcode beyond the setting of vector spaces. In this talk, I will generalize the persistence diagram to the setting of constructible persistence modules valued in any symmetric monoidal category. For example, the category of sets, the category of vector spaces, and the category of abelian groups are symmetric monoidal categories. As an immediate consequence, we can finally talk about persistent homology over integer coefficients!

2095 - Persistent Homology on Grassmann Manifolds for Analysis of Hyperspectral Movies

Lori Ziegelmeier, Macalester College

We present an application of persistent homology to the detection of chemical plumes in hyperspectral movies of Long-Wavelength Infrared data which capture the release of a quantity of chemical into the air. Regions of interest within the hyperspectral data cubes are used to produce points on the real Grassmann manifold $G(k, n)$ (whose points parameterize the k-dimensional subspaces of $\mathbb{R}^n$, contrasting our approach with the more standard framework in Euclidean space. An advantage of this approach is that it allows a sequence of time slices in a hyperspectral movie to be collapsed to a sequence of points in such a way that some of the key structure within and between the slices is encoded by the points on the Grassmann manifold. This motivates the search for topological structure, associated with the evolution of the frames of a hyperspectral movie, within the corresponding points on the Grassmann manifold. The proposed framework affords the processing of large data sets while retaining valuable discriminative information. In this paper, we discuss how embedding our data in the Grassmann manifold, together with topological data analysis, captures dynamical events that occur as the chemical plume is released and evolves.

2096 - Studying Knots Via Heat Maps

Isabel Darcy, University of Iowa

Heat maps have been used to visualize pseudo 2-dimensional persistence when one wishes to visualize changes in homology using more than one parameter. Given points taken uniformly from a knot, we create a simplicial complex for a fixed epsilon by forming the Rips complex obtained from connecting points with edges if the distance between the points is less than epsilon. We create the 1-dimensional persistence homology barcode for the filtration formed from increasing epsilon. One can create a 1-dimensional heatmap from this barcode by encoding the betti number at each fixed epsilon via a heatmap color. In other words, we can color the interval [0, M) by assignment a color to each epsilon in this interval based on the betti number of the Rips complex formed at time epsilon. One dimensional heat maps can be stacked together to form a 2-dimensional heat map in order to visualize simplicial complex formation involving a second parameter. For knots our second parameter involves looking at superlevel sets based on local curvature. We apply this technique to Lissajous knots. This is joint work with Katie Betancourt, V. Gerardi, G. Heo, R. Neville, M. Pietrosanu, and M. Tsuruga and was supported by WinCompTop.

2097 - Topological Measures of Snow Surface Roughness

Iuliana Oprea, Colorado State University

Understanding the spatiotemporal changes in snow surface - the interface between the atmosphere and the Earth - can improve knowledge of hydrologic processes within the snowpack and their impact on melt dynamics and, further, on the climatology of the environment. In this talk topological data analysis and roughness measures are proposed for the study of the characteristics of anisotropic patterns observed in the snow surface and the estimate of the snow surface roughness.

EIT 325: Interactions Among Analysis, Optimization And Network Science

Organizers: Pietro Poggi-Corradini, Nathan Albin
Speakers: Dominique Zosso, Lizaveta Ihnatsyeva, Heman Shakeri, Kevin Wildrick

2098 - Primal-Dual Methods for p-Modulus on Graphs

Dominique Zosso, Department of Mathematical Sciences, Montana State University

Recently the notion of p-Modulus has been extended to families of walks on graphs by Albin, Poggi-Coradini, et al. Here we propose to employ a primal-dual hybrid gradients scheme (Chambolle and Pock) to the greedy algorithm for p-Modulus computation. All optimization steps are simple first order. In the particular case of 2-modulus, the proposed scheme simplifies into a boosted dual problem. We compare against existing methods.

2099 - Functions Of Fractional Smoothness On Metric Measure Spaces

Lizaveta Ihnatsyeva, Kansas State University

Function spaces with fractional order of smoothness are actively applied in partial differential equations, calculus of variations and optimization. Recently there has been an increasing interest in extending the scope of classical analytic and geometric theories from the Euclidean space to more general metric spaces equipped with a measure. This direction of the research is, in particular, motivated by the current demands for analysis on topological manifolds, fractals, graphs, and on Carnot-Caratheodory spaces. In this talk I would like to discuss several analogues for function spaces of fractional smoothness, Besov spaces and Triebel-Lizorkin spaces, in the setting of a metric space with a doubling measure.

3000 - Analyzing Loop Structures In Networks

Heman Shakeri, Kansas State University

We study the structure of loops in a network using the notion of modulus of loop families. We introduce a new measure of network clustering by quantifying the richness of certain families of loops. Modulus tries to minimize the expected overlap among loops by spreading the expected link-usage optimally. We propose weighting networks using these expected link-usages to improve classical community detection algorithms. We show that the proposed method enhances the performance of algorithms, such as spectral partitioning and modularity maximization, on standard benchmarks.

3001 - Metric Spaces of Small Cotype

Kevin Wildrick, Montana State University

Embedding an abstract metric space into a space with more structure while distorting the notion of distance in a controlled way is a useful tool in situations ranging from classical Riemannian geometry to data science. We will discuss a few results about such embeddings and focus on an obstruction to embedding, Metric Co-type, introduced by Mendel and Naor. We examine the metric cotype of tree-like metric spaces. This is joint work with Ellen Veomett.

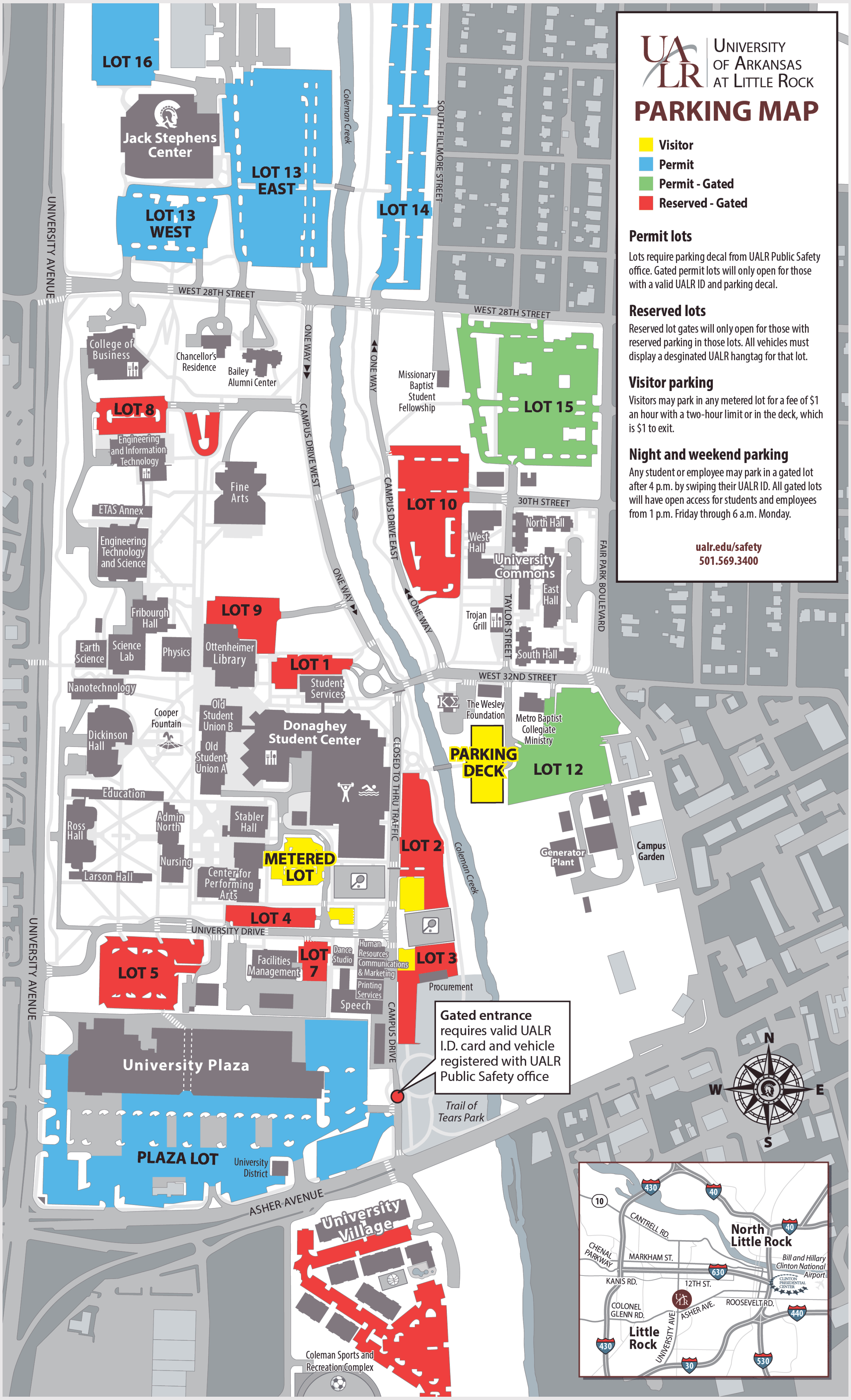
ETAS 229: No scheduled talks

ETAS 230: No scheduled talks

ETAS 480: No scheduled talks

ETAS 483: No scheduled talks

NOTES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Larson Hall
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LOT 3
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University Village
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